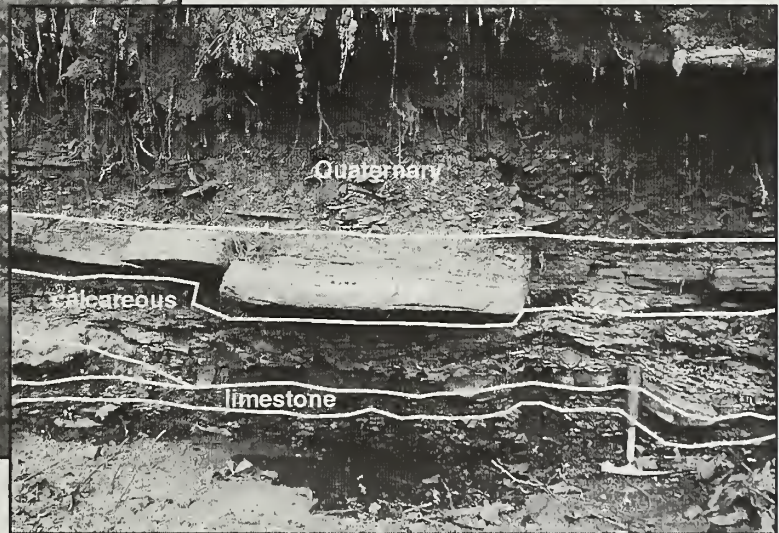
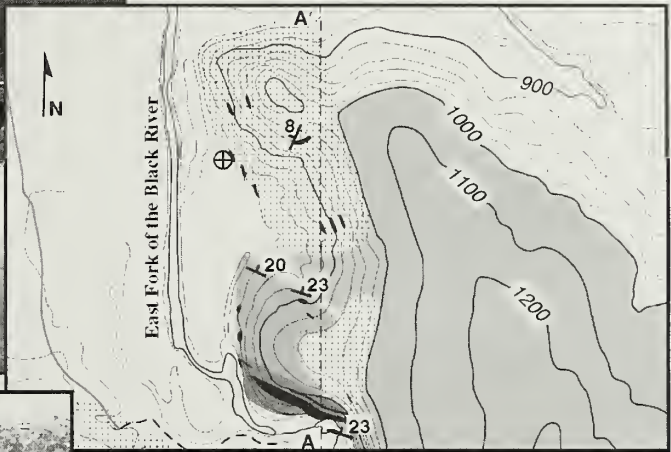


Guidebook for Field Trips for the Thirty-Fifth Annual Meeting of the North-Central Section of the Geological Society of America

April 23–24, 2001

David Malone, Editor



ISGS Guidebook 33 2001

George H. Ryan, Governor

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

EDITOR'S MESSAGE

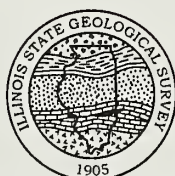
Greetings from the Executive Committee of the North Central Section of the Geological Society of America! As geologists, we all recognize the great importance of field experiences. This year's meeting includes a diverse and excellent set of field trips. Collectively, this year's field trips visit a broad spectrum of the geologic features of Illinois and Missouri that range in age from Precambrian to Quaternary. These trips present a number of new ideas and interpretations that will broaden the perspectives of all field trip participants. Your participation, interaction, and exchange of ideas with the field trip leaders are encouraged at all times

These trips are the culmination of the time and energy freely given by a number of individuals. I would like to thank and recognize the field trip leaders for their hard work in planning the field trips and preparing the individual field guides. I would also like to thank the technical reviewers at Illinois State University and the Illinois State Geological Survey for their efforts. I appreciate the efforts of Jon Goodwin and the publication staff at the Illinois State Geological Survey for their substantial work in preparing this field guide. A special thanks goes out to the property owners who have been most helpful in planning these trips.

I look forward to a successful set of field trips!

David H. Malone
Department of Geography-Geology
Illinois State University

Cover photos, clockwise from upper left: *Rafters negotiating Wildcat Rapids; geologic map of the northern part of Johnson Shut-Ins; exposed strata at the Jubilee Lodge stop; cobbly limestone and chert overlying crudely stratified silt in the Mason Hollow Section.*



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615 East Peabody Drive

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The St. Francois Mountains of Missouri: Window into the Mesoproterozoic

***James A. Walker, Northern Illinois University,
Vernon M. Brown, University of Toledo, Gary R. Lowell,
Southeast Missouri State University, and
Michael D. Stallings, University of Missouri***

INTRODUCTION

The St. Francois Mountains, located in southeastern Missouri, are host to the only sizable exposures of an extensive belt of Mesoproterozoic igneous rocks that conservatively stretches from northwestern Texas to southern Michigan (fig. 1-1). Silicic igneous rocks appear to dominate the entire belt; hence, it has often been referred to as the Granite-Rhyolite Terrane (Thomas et al., 1984). More recently, the Granite-Rhyolite Terrane has been subdivided into two separate Mesoproterozoic provinces by Van Schmus et al. (1993): (1) the ca. 1,470 Ma Eastern Granite-Rhyolite Province and (2) the ca. 1,370 Ma Southern Granite-Rhyolite Province (fig. 1-1). The tectonic setting of these vast granite-rhyolite provinces remains enigmatic (e.g., Bickford and Anderson, 1993). Rhyolitic ash-flow tuffs and granites are the preponderant Mesoproterozoic lithologies of the St. Francois Mountains (e.g., Bickford et al., 1981). In general, granite is the dominant lithology of the northeastern portions of the St. Francis Mountains, and rhyolite is much more abundant to the southwest (Sides et al., 1981). This skewed distribution has been attributed to southwestward tilting and subsequent erosional beveling some time after the cessation of magmatic activity (e.g., Sides et al., 1981).

Most of the granites and rhyolites of the St. Francois Mountains have yielded U-Pb zircon ages of $1,470 \pm 30$ Ma; i.e., they are part of the Eastern Granite-Rhyolite Province (Van Schmus et al., 1996). The coeval ages of many of the igneous rocks suggest that there was one main magmatic pulse centered around 1,470 Ma. Brown (1983, 1989) provides geologic evidence that this main magmatic pulse was initiated in the southern St. Francois Mountains. Other geologic studies indicate that magmatism then became focused in the eastern St. Francois Mountains, culminating with the formation of the Butler Hill Caldera (Sides et al., 1981; Lowell, 1991). Magmatic activity then shifted to the west and again may have climaxed with caldera formation (Sides et al., 1981). Sides et al. (1981) have dubbed this western caldera the Taum Sauk Caldera.

Two granite plutons in the western St. Francois Mountains, the Munger and Graniteville granites, have rendered ages of ca. 1,370 Ma (Van Schmus et al., 1996). These plutons could therefore represent isolated, outlying magmatism associated with the Southern Granite-Rhyolite Province (Bickford and Anderson, 1993; Van Schmus et al., 1996), or alternatively, indicate that much of the magmatic activity in the western St. Francois Mountains, including production of the hypothesized Taum Sauk Caldera, is actually considerably younger than magmatism to the east and southeast (Anderson et al., 1969).

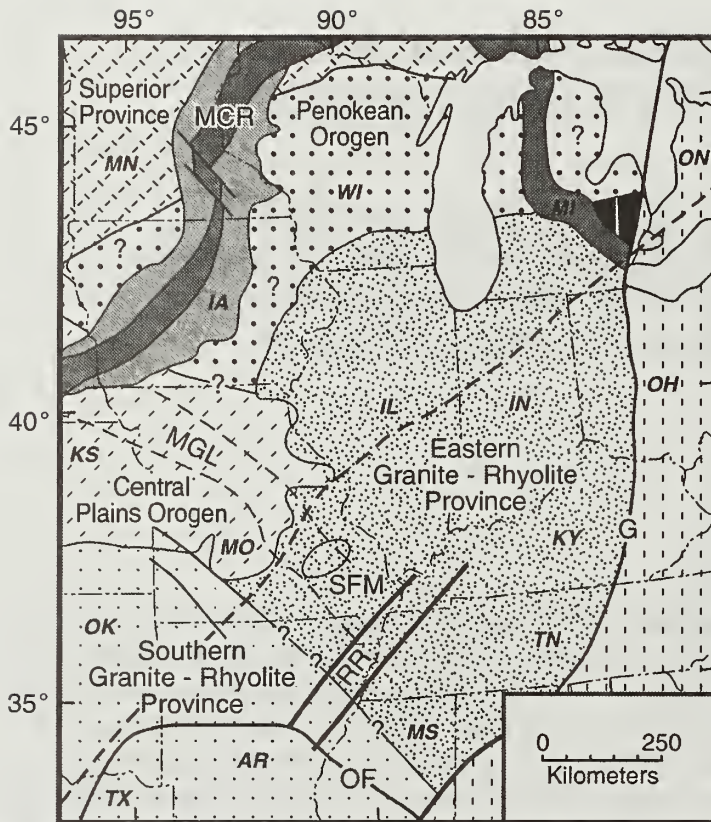


Figure 1-1. Major geologic features of the central Midcontinent region (modified after Van Schmus et al., 1996). G = Grenville front, OF = Ouachita front, MCR = Midcontinent rift, MGL = Missouri gravity low, RR = Reelfoot rift, SFM = St. Francois Mountains. Dashed line is inferred eastern limit of pre-1,600 Ma continental crust as discussed by Van Schmus et al. (1996).

Although volumetrically subordinate, mafic and intermediate igneous rocks are present within the St. Francois Mountains (Amos and Desborough, 1970; Sylvester, 1984; Pippin, 1996). The mafic and intermediate igneous rocks of the St. Francois Mountains occur as hypabyssal dikes and sills, small stocks, and lava flows (Amos and Desborough, 1970; Berry and Bickford, 1972; Sylvester, 1984; Pippin, 1996). Bowring et al. (1992) suggested that the mafic rocks fall into two chronological groups: a 1,380–1,330 Ma group, which accompanied the youngest silicic magmatism, and a post-siliceous, ca. 1,200 Ma group. These groups have been referred to informally as the Silvermines and Skrainka groups, respectively (Sylvester, 1984; Pippin, 1996). Other geochronological results for the mafic rocks of the St. Francois Mountains are consistent with this interpretation (Honda et al., 1985; Rämö et al., 1994). Nevertheless, there are good reasons for believing that mafic magmas were present during the entire magmatic history of the St. Francois Mountains. First, Van Schmus et al. (1996) have

recently obtained Sm-Nd isochron ages on mafic plutons in the subsurface of Missouri that overlap those of main phase granites and rhyolites. Second, rare mafic lavas have been found intercalated with main phase silicic volcanics (Satterfield, 1966; Brown, 1983; Pippin, 1996). Third, mafic enclaves and mafic lithics are common in main phase granites and rhyolitic ash-flow tuffs, respectively (Sides, 1978; Nusbaum, 1980; Sides et al., 1981; Lowell and Young, 1999). In addition, Lowell and Young (1999) have demonstrated that most of the mafic enclaves in one particular granite, the Silvermine Granite, although intermediate in composition, probably originate through the hybridization of mafic and silicic magmas. Fourth, gravity and magnetic anomaly data suggest that mafic plutons may be more abundant in the upper crust below the St. Francois Mountains (Hildenbrand et al., 1996). Lastly, mantle-derived basaltic magmas likely flooded and provided heat to this large, caldera-producing silicic magmatic system throughout its entire history (Hildreth, 1981; Kay et al., 1989, Bickford and Anderson, 1993).

The Precambrian rocks of the St. Francois Mountains have been variably affected by alteration, metasomatism, and mineralization (Bickford and Mose, 1975; Wenner and Taylor, 1976; Brown et al., 1989; Lowell, 1991; Sutton and Maynard, 1996). Wenner and Taylor (1976) and Lowell (1991) have suggested that hydrothermal alteration/K-metasomatism has been pervasive throughout the region; Cullers et al. (1981) argued for more localized metasomatic alteration. The Precambrian mineralization has produced magnetite-hematite-apatite ore deposits (e.g., Brown et al., 1989).

The Mesoproterozoic igneous rocks are in nonconformable contact with various overlying Upper Cambrian marine sedimentary rocks. The oldest of these is the Lamotte Formation (Sandstone), which has been described by Ojakangas (1963) and Houseknecht and Ethridge (1978). Above the Lamotte is the Bonneterre Formation (Dolomite), which has been the focus of many studies including those of Lyle (1977), Gregg (1985), Gregg and Shelton (1990), Tobin (1991), and Shelton et al. (1992).

The field trip has been designed in an attempt to provide an overview of the entire magmatic history of the St. Francois Mountains in selected extended stops. Daily stops are shown in figure 1-2 along with outcrops of Mesoproterozoic rocks. Other interesting field stops for these rocks are included in studies by Lowell (1975), Kisvarsanyi (1976), Biggs (1987), Brown et al. (1989), and Kisvarsanyi and Hebrank (1993). Each of the field stops is described in the planned order of visit.

SITE DESCRIPTIONS

Stop 1-1: Graniteville Granite at the Missouri Red Quarry

Location Graniteville 7.5-minute Quadrangle (fig. 1-3). The quarry is on Iron County 96, 4 mi north of its intersection with Missouri Highway 21 (note that the roads have changed in the central and west-central portions of this area from their locations shown in the 1968 quadrangle map. On this map, the quarry is directly off MO 21 north of Graniteville). Quarry entrance is on the northern side of the road. The quarry is privately owned. You must get prior permission to visit. Graniteville granite is also exposed in Elephant Rocks State Park, just southwest of the quarry, and is accessible via MO 21.

Outcrop Description The Missouri Red Quarry has excellent exposures of the Graniteville Granite, which has a U-Pb zircon age of $1,358 \pm 25$ Ma (Van Schmus et al., 1996). The Graniteville may be a somewhat isolated outlier of the Southern Granite-Rhyolite Province (Van Schmus et al., 1996) or it may signify that the western St. Francois Mountains were host to a second period of significant silicic magmatism. Drill core information indicates that the Graniteville pluton occupies an 11 km by 15 km fault-bounded block within the hypothesized Taum Sauk Caldera (Kisvarsanyi, 1980; Sides et al., 1981). Hence, it is tempting to call the Graniteville the western equivalent of the Butler Hill Granite. The Graniteville is a distinctive brick-red granite composed of microcline, quartz, plagioclase, biotite, and muscovite (Sides et al., 1981; Nabelek and Russ-Nabelek, 1990; Stallings, 1998). Accessory minerals include fluorite, cassiterite, magnetite, pyrite, zircon, and apatite (Sides et al., 1981; Stallings, 1998). Stallings (1998) recognizes four textural varieties of the Graniteville: (1) a coarse-grained red granite, (2) a coarse-grained gray granite, (3) a fine-grained red granite, and (4) a fine-grained gray granite. Contacts between the textural variants are typically gradational. However, dikes and stringers of red granite crosscut the gray granites indicating a younger age for the red granites. Their red coloration is likely due to minute amounts of hematite dispersed in microcline (Wenner and Taylor, 1976). Rapakivi texture occurs within both fine-grained varieties of granite, but less commonly in the coarser grained types (Stallings, 1998). Numerous mafic enclaves are present in the Graniteville Granite. The Graniteville is a high-Si granite with many of the chemical characteristics of typical A-type granites (Stallings, 1998). The Graniteville is cut by numerous primary fractures striking northeast. These tension fractures are filled by subsolidus pyrite and mica and are paralleled by late-stage pegmatites and quartz veins (Stallings, 1998).

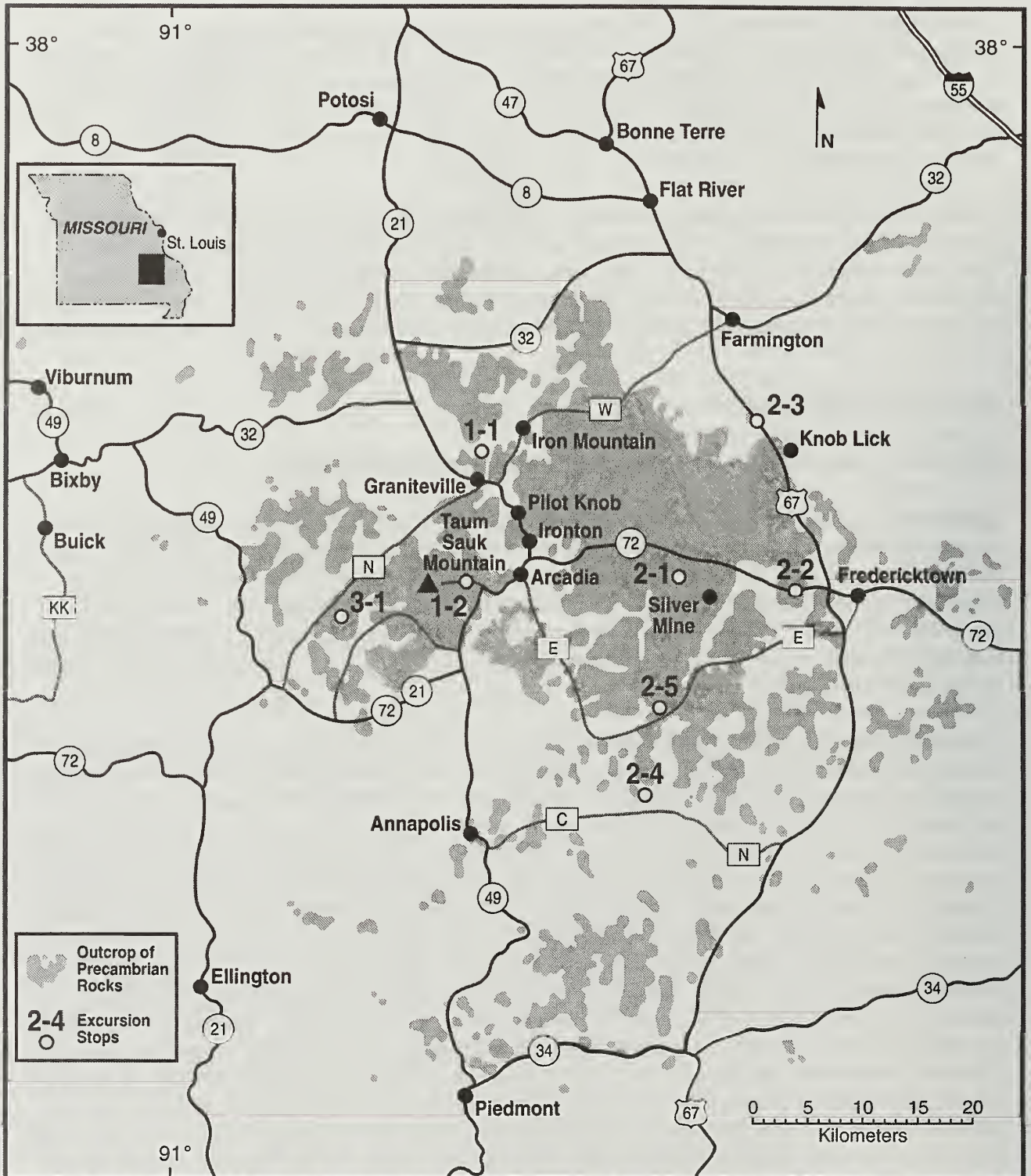


Figure 1-2. Outcrops of Precambrian rocks in the St. Francois Mountains modified from Kisvarsanyi and Hebrank (1993). Also shown are approximate locations of field trip stops.

Stop 1-2: Royal Gorge Rhyolite on Russell Mountain (time permitting)

Location Ironton 7.5-minute Quadrangle (fig. 1-4). From Arcadia, Missouri, take MO 72/21 south about 4 mi to intersection with MO CC. Turn right on CC and travel west 1.5 mi. Pull off on left by the trail head.

Outcrop Description Exposed immediately southeast and farther along the trail is the Royal Gorge Rhyolite (fig. 1-4) (Berry, 1976). This unit is believed to be part of the relatively younger volcanic sequence in the western St. Francois Mountains, stratigraphically below the climactic ash flow in the west, the Taum Sauk Rhyolite (Table 1-1; Sides et al., 1981). Van Schmus et al. (1996) reported a U-Pb zircon age of $1,503 \pm 20$ Ma for the Royal Gorge Rhyolite. The Royal Gorge Rhyolite is a red to maroon rhyolitic lava flow having a fine-grained matrix of devitrified glass with about 5% quartz and alkali feldspar phenocrysts (Berry, 1970, 1976; Sides et al., 1981). The Royal Gorge Rhyolite ranges in thickness from a few meters to more than 700 m (Berry, 1970, 1976).

At this stop, the Royal Gorge Rhyolite exhibits arresting flow banding and flow folding. Flow bands vary in thickness from less than a millimeter to a few centimeters (Berry, 1970). The darker bands consist of devitrified glass with a well-developed snowflake texture, and the lighter bands consist of recrystallized pumiceous material with pronounced secondary crystallization of quartz, feldspar, fluorite, calcite, and iron oxide (Berry, 1970). Individual bands can be traced for more than 100 m on Russell Mountain (Berry, 1970). According to Berry (1970), flow banding and folding are only characteristic of the upper portions of the Royal Gorge Rhyolite in outcrops on Russell and Taum Sauk Mountains. The lower portion of the lava is said to be massive (Berry, 1970). Massive lava can be viewed in Royal Gorge (further south of the CC intersection along MO 72/21 about 1.4–1.8 mi, fig. 1-4).

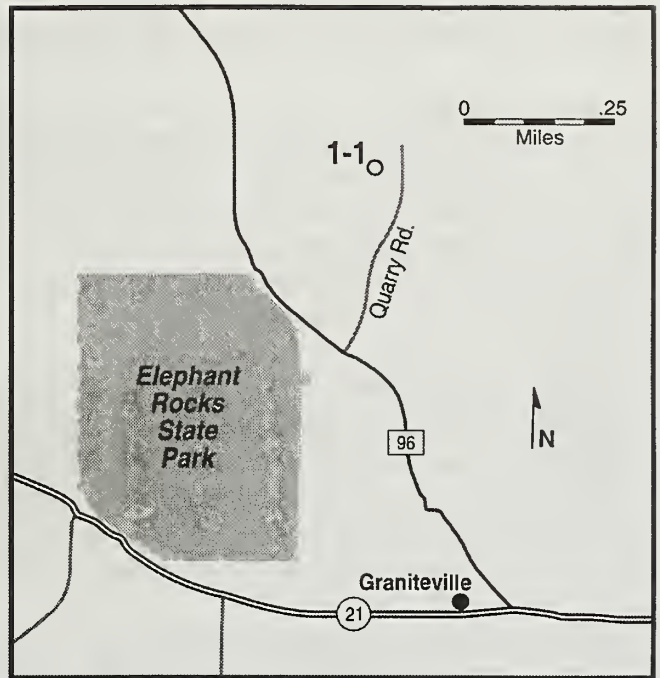


Figure 1-3. Location of Stop 1-1.

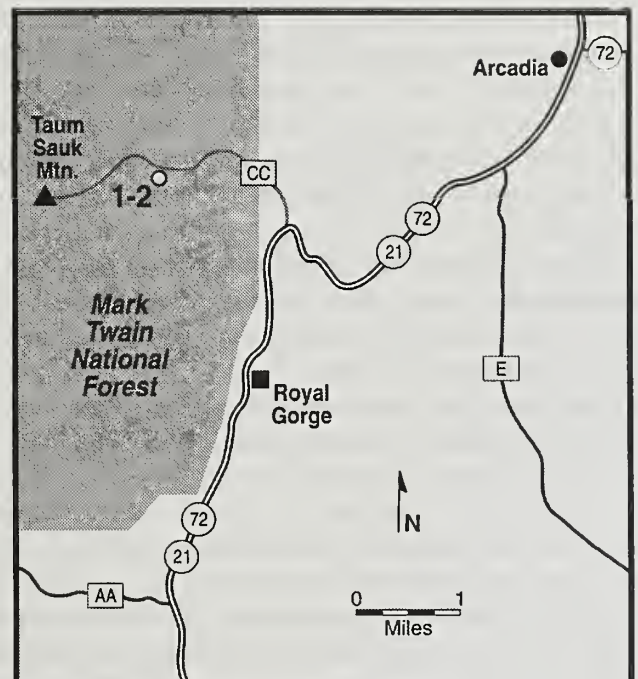


Figure 1-4. Location of Stop 1-2.

Stop 2-1: Silvermine Granite at Tiemann Shut-In

Location Rhodes Mountain 7.5-minute Quadrangle (fig. 1-5). Take MO 72 west for approximately 7.5 mi from its intersection with U.S. 67 (or take MO 72 east about 9.9 mi from Arcadia, Missouri, past Roselle) and turn south onto Millstream Gardens State Park road (unpaved). Bear left at the first intersection to avoid the well-marked private road, bear right at the second intersection, and then turn left at the third intersection continuing to the parking lot and pavilion. The parking lot is about 1.2 mi from MO 72. This stop is best when the river is low and kayakers are scarce. Watch out for snakes.

Outcrop Description From the parking lot, follow the hiking trail east, crossing the covered bridge. Turn right immediately after the bridge on the small trail leading to the river. The river channel exposes magnificent swarms of granite-hosted, pillow-shaped enclaves that record mingling and hybridization between silicic and mafic melts (Lowell and Young, 1999). The hybrid enclaves constitute more than 50% of some outcrops. Numerous aplite dikes cut both granites and enclaves. Mafic dikes can also be viewed at this stop.

The host rock is the Silvermine Granite, one of the post-collapse ring plutons of the Butler Hill Caldera (Sides et al., 1981; Lowell, 1991). Van Schmus et al. (1996) gave a U-Pb zircon age of $1,484 \pm 07$ Ma for the Silvermine Granite. The dominant rock in this pluton is a white, medium-grained granite composed of plagioclase, perthite, quartz, biotite, and amphibole. Accessory phases are apatite, magnetite, zircon, and titanite. The pluton is roofed by a thin, enclave-free, fine-grained granophyre that lacks titanite and ferromagnesian minerals (Scully, 1978; Bickford et al., 1981; Sides et al., 1981; Lowell, 1991).

The enclaves are hosted by medium-grained Silvermine Granite and form a mesocratic-leucocratic series corresponding to tonalite-granite that can be successfully modeled as hybrids of Silvermine Granite and Silvermines group basalts (Lowell and Young, 1999). The enclaves are fine-grained, mostly darker than their host, and chaotically mixed in terms of size, shape, and composition. Most enclaves exhibit chilled margins with lobate crenulations convex toward the felsic host, but some enclave margins are recrystallized and coarser than the interior. Margin texture commonly changes from sharp-crenulate to diffuse-veined over a short distance, which may reflect rupture of brittle, chilled rims of partially molten pillows and mingling between melts. Two types of light-colored, felsic enclaves are recognized by Lowell and Young (1999): (1) those hosted by granite are mottled pink-gray, fine-grained, and concentrically zoned and reach 30 cm in diameter; and (2) those hosted by large, dark tonalitic pillows are pink, coarse-grained, and range up to 10 cm in diameter. The latter may appear in close proximity to fine-grained enclaves of similar size and shape that are more mafic than their host pillow. Back-veining of the pillow enclaves is common and assumes a variety of forms depending upon the state of pillow solidification during injection.

Enclave mineralogy is similar to that of the granite host, but mineral proportions differ, especially at the mafic end of the enclave spectrum. Notable features include radial clusters of fine-grained acicular amphibole, rapakivi, and antirapakivi mantled feldspars, rare ocellar quartz, and abundant (1%) acicular apatite with aspect ratios up to 70:1. Varying amounts of coarse, granite-derived xenocrysts impart a porphyritic appearance and textural heterogeneity to the larger enclave pillows. If xenocrysts are neglected, the enclaves constitute a gradational textural/modal series between tonalite and granite. The tonalitic enclave texture is a plagioclase lath framework filled by interstitial quartz and perthite that is accompanied by radial clusters of acicular amphibole (1–8 mm).

Amphibole content and grain size decrease as felsic character increases, but the distinctive skeletal-acicular-radial morphologies are retained in the most felsic enclaves. See Lowell and Young (1999) for further petrographic details, and for mineral analyses, whole rock chemistry, and interpretation of mingling phenomena.

The aplites are pink, fine-grained dikes up to 0.7 m wide that fill vertical northeast- and northwest-trending conjugate fractures. The aplites also exhibit chilled margins and contain angular fragments of host granite and enclave material. The aplites are composed of quartz, alkali feldspar, and biotite with minor apatite, zircon, epidote, and opaque phases. For modal and chemical data on the aplites, see Lowell and Young (1999).

The mafic dikes are black to greenish gray microphyritic basalts with chilled margins. They are composed of plagioclase, clinopyroxene, and opaques and may contain up to 25% xenocrystic quartz, alkali feldspar, and plagioclase (Lowell and Young, 1999). The presence of xenocrysts, the lack of olivine, and various trace element characteristics place these dikes into the Silvermines mafic group of Sylvester (1984). Again, for modal and chemical data, see Lowell and Young (1999).

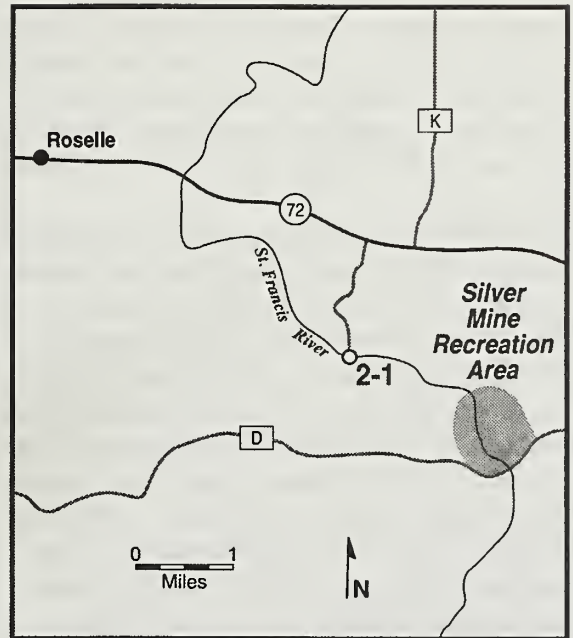


Figure 1-5. Location of Stop 2-1.

Stop 2-2: Grassy Mountain Ignimbrite and Skrainka Basalts Along Missouri Highway 72

Location Fredericktown 7.5-minute Quadrangle (fig. 1-6). Outcrops along MO 72, 1.7 mi west of intersection with U.S. 67. Pull well off the highway onto the shoulder of MO 72.

Outcrop Description Exposed on the north side of MO 72 is the Grassy Mountain Ignimbrite cut by two Skrainka-group mafic dikes. These same Precambrian units are present on the south side of MO 72 and are nonconformably overlain by two younger sedimentary units.

The Grassy Mountain Ignimbrite is the product of the climactic explosive eruption in the eastern St. Francois Mountains (e.g., Sides et al., 1981). Its measured volume at present is 32 km³, strongly suggesting that its eruption led to caldera formation (Sides et al., 1981). The hypothesized location and evolution of this caldera, referred to as the Butler Hill Caldera, are discussed in detail by Sides et al. (1981) and Lowell (1991). The Grassy Mountain Ignimbrite is a dark maroon to black rhyolitic ash-flow tuff (Sides et al., 1981). Although it can look deceptively phaneritic in hand specimen, the Grassy Mountain Ignimbrite is porphyritic with about 15–25% phenocrysts of perthitic feldspar and quartz (Shuster, 1978; Sides et al., 1981). The matrix is totally recrystallized to a granular to granoblastic aggregate of quartz and feldspar (Shuster, 1978; Sides et al., 1981). Sides et al. (1981) suggest that the recrystallization was part of the primary devitrification of this thick pyroclastic flow deposit (see Lofgren, 1971). Flattened pumice fragments and lithic fragments are generally rare; the former is said to be more abundant in the

upper portions of the unit (Shuster, 1978). Shuster (1978) has shown that the Grassy Mountain is quite compositionally uniform, showing no petrographic or chemical zonations. It is a high-Si rhyolite (Bickford et al., 1981).

The dikes are chemically part of the Skrainka group of mafic rocks; hence, they are believed to post-date all of the silicic magmatism of the region (Honda et al., 1985; Bowring et al., 1992; Rämö et al., 1994). According to Sylvester (1984), most of the Skrainka dikes trend N30°E, distinct from the dominant strike of the older Silvermines dikes. The Skrainka dikes at this locality have about 7–8 wt% MgO (Pippin, 1996). They are medium- to fine-grained olivine diabases, containing more plagioclase feldspar than clinopyroxene (Sylvester, 1984; Pippin, 1996). The larger dike is about 1.3 m wide and the smaller one



Figure 1-6. Location of Stop 2-2.

to the west is about 0.4 m wide. Both dikes have very sharp contacts with the host Grassy Mountain Ignimbrite. On the south side of the highway, the larger dike is extensively altered.

The oldest sedimentary unit has been described as a basal boulder conglomerate by Kisvarsanyi and Hebrank (1987). The boulders in this unit are mostly of weathered Precambrian igneous rocks, suggesting that this unit may be a Precambrian weathering surface (e.g., Sutton and Maynard, 1996). Overlying the basal conglomerate is the Bonneterre Formation consisting of coarse sandy dolomite and dolomite (Kisvarsanyi and Hebrank, 1987).

Stop 2-3: Butler Hill Granite Along U.S. Highway 67

Location Wachita Mountain 7.5-minute Quadrangle (fig. 1-7). Outcrop is along the west side of U.S. 67, 10.3 mi north of intersection with MO 72. Pull off the highway as far as possible.

Outcrop Description Exposed at this outcrop is the Butler Hill Granite, aplite dikes, and the nonconformity with the overlying Lamotte Formation. The Butler Hill Granite is thought to be the solidified upper portion of the magma chamber that also produced the Grassy Mountain Ignimbrite and the Butler Hill Caldera (Sides et al., 1981). Two samples of the Butler Hill Granite have yielded U-Pb zircon ages of $1,465 \pm 32$ Ma and $1,480 \pm 30$ Ma (Van Schmus et al., 1996). The Butler Hill Granite crops out in a wide area of the northeastern St. Francois Mountains (Sides et al., 1981). The granite intrudes Grassy Mountain Ignimbrite and rocks of the even older Lake Killarney Formation on its western, southern, and eastern edges (Sides et al., 1981), indicating that the granite was emplaced during the resurgence of the Butler Hill Caldera after eruption of the Grassy Mountain Ignimbrite (Sides et al., 1981). The grain size of the granite decreases systematically to the southwest, one of the strong indicators for post-magmatic southwestern tilting and erosional leveling of the St. Francois Mountains (e.g., Sides et al., 1981). Perthite, quartz, biotite, and plagioclase are the common minerals in the Butler Hill Granite (Blaxland, 1974; Sides et al., 1981; Nabelek and Russ-Nabelek, 1990). In places, biotite is largely altered to chlorite (Nabelek and

Russ-Nabelek, 1990). Amphibole and muscovite are rare, and important accessory minerals include fluorite, apatite, and zircon (Sides et al., 1981). At this stop, the Butler Hill exhibits well-developed rapakivi texture with alkali feldspar ovoids as large as 3 cm in diameter mantled by plagioclase (Lowell and Sides, 1973; Hebrank and Kisvarsanyi, 1976). The Butler Hill is a high-Si granite with major element compositions similar to the Grassy Mountain Igneimbrite (Bickford et al., 1981). The Butler Hill becomes progressively more altered toward the nonconformity, where it is extensively altered (Blaxland, 1974). This paleoweathering surface and others like it in the region have undergone a series of alteration events (Duffin, 1989; Sutton and Maynard, 1996).

The aplite dikes are orange, fine-grained, equigranular rocks composed largely of quartz and alkali feldspar. Nabelek and Russ-Nabelek (1990) indicate that the Butler Hill aplites are also distinguished by unevenly distributed miarolitic cavities. Aplites are generally interpreted as late-stage differentiates in this case of the Butler Hill magmatic system (e.g., Nabelek and Russ-Nabelek, 1990).

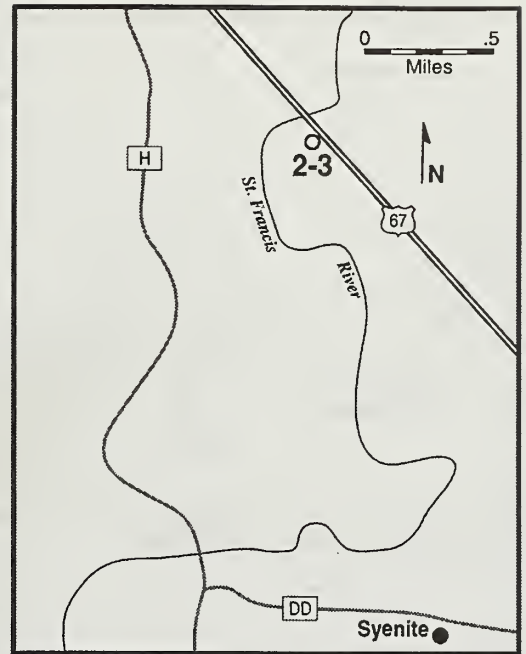


Figure 1-7. Location of Stop 2-3.

At this outcrop, the Butler Hill Granite is nonconformably overlain by the Lamotte Formation. The Lamotte Formation is dominated by quartz-cemented quartz arenite, but includes conglomerate, arkose, and litharenite as well (Ojakangas, 1963; Houseknecht and Ethridge, 1978). Here it exhibits both cross- and graded bedding.

Stop 2-4: Tile Red and Crane Pond Tuffs at Leatherwood Creek Shut-Ins

Location Des Arc Northeast 7.5-minute Quadrangle (fig. 1-8). Coming from the east, take U.S. 67 approximately 17 mi south of Fredericktown to junction with MO N. Follow N west about 5 mi to its junction with MO C. Take C west about 2.8 mi and turn right onto Madison County 424 (unpaved). Coming from the west, take MO 49 to Annapolis, turn left onto MO C, and travel 9.2 mi turning left onto Madison County 424. Follow Madison County 424 west about 2.2 mi to Leatherwood Creek Shut-Ins. Note that 424 may be a challenge in bad weather and the Shut-Ins are on private property. Permission from the owners must be secured before visiting this site. The shut-in below the dam at Crane Lake, a few miles to the west, affords public access and exposures of the same volcanic units.

Outcrop Description The Leatherwood Creek Shut-Ins area has excellent exposures of the Tile Red Tuff (Weixelman, 1959), the Crane Pond Tuff (Brown, 1983, 1988), and a younger volcanic breccia. The Tile Red Tuff is well exposed in the bed of Leatherwood Creek. The Crane Pond Tuff is exposed on the hillside to the east of the shut-in, and the volcanic breccia crops out on the hillside to the west (Brown, 1988).

All of these units are believed to underlie the Lake Killarney Formation, the oldest unit in the eastern St. Francois Mountains (Brown, 1983). Hence, they may represent some of the earliest magmas

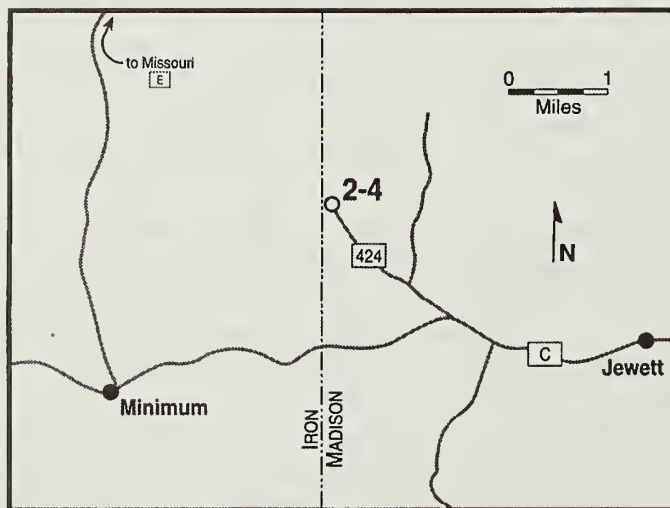


Figure 1-8. Location of Stop 2-4.

extruded in the region (Brown, 1983). Both ash-flow tuffs are exposed in a series of five knobs trending generally east-west across the southern part of the Des Arc Northeast 7.5-minute Quadrangle (Brown, 1988). The Leatherwood Creek exposure is the easternmost knob. Here, the Crane Pond lies stratigraphically above the Tile Red. In the four knobs to the west, this stratigraphic order is reversed. At this outcrop, Tile Red pyroclastics were depressed and deformed by emplacement of the Crane Pond, suggesting both units were produced in a single eruption. Brown and Kumar (1986) conclude that the two tuffs were part of a zoned magma chamber, with the Tile Red representing the more SiO₂-rich, crystal-poor, cap of the chamber.

The Tile Red is a tile red rhyolitic ash-flow tuff with about 3–4% phenocrysts of alkali feldspar, plagioclase, and quartz. It has a maximum thickness of 18 m. It is densely welded and has a well-developed basal lithophysal zone. At the Leatherwood Creek exposure, this basal zone also has orbicular devitrification structures up to 20 cm in diameter. The groundmass of the tuff is devitrified, but not recrystallized, and ghost glass shards are readily observable under the microscope. The Crane Pond is a purple to red rhyolitic ash-flow tuff with about 15–16% phenocrysts of plagioclase, alkali feldspar, and quartz. Its maximum thickness is 50 m. Its matrix is devitrified and recrystallized and locally exhibits a snowflake texture. Small, quartz-filled lenticular lithophysae are present throughout the unit but are larger and more common near its base. The volcanic breccia has clasts of both tuffs and other volcanics (Brown, 1983, 1988).

Stop 2-5: Rhyolitic Ash-Flow Tuffs and Basaltic Andesite Lava at Marble Creek Campground (time permitting)

Location Des Arc Northeast 7.5-minute Quadrangle (fig. 1-9). On MO E, 9.9 mi southeast from its intersection with MO 72/21 south of Arcadia, Missouri, turn left into the campground and use the parking lot immediately to the right.

Outcrop Description Exposed along Marble Creek immediately to the east is the Lower Campground Tuff of Brown (1983, 1988). Exposed along MO E west of the parking area and on the knob south of E is the Upper Andesite of Brown (1983, 1988), also known as the Marble Creek Andesite (Satterfield, 1966) and the Blue School Basalt (Weixelman, 1959). Overlying the Upper Andesite on the summit of the knob are float blocks of another ash-flow tuff called the Upper Campground Tuff (Brown, 1983, 1988).

These volcanics are again believed to underlie the Lake Killarney Formation, which caps Black Mountain, visible to the northeast (Brown, 1983). They occupy a structural hinge zone that is suggested to form the southern boundary of the Lake Killarney Caldera, which has been postulated

to have formed during eruption of the Lake Killarney Formation, prior to production of the Butler Hill Caldera (Brown, 1983, 1989).

The Lower Campground Tuff is a maroon, rhyolitic ash-flow tuff with about 10% phenocrysts of feldspar. It may reach 35 m in thickness. Thin, stringer-like lenticular lithophysae are locally present. The tuff's matrix is devitrified and partially recrystallized with occasional ghost glass shards observable under the microscope. It has about 74 wt% SiO₂. The Upper Andesite is a black to dark green aphyric to porphyritic lava with phenocrysts of plagioclase. The groundmass is subophitic to trachytic and composed of plagioclase, clinopyroxene, and opaques. The rock has about 52 wt% SiO₂ and 5 wt% MgO and hence is a basic, or basaltic, andesite (Pippin, 1996). The Upper Campground Tuff is a dark maroon to bleached white rhyolitic pyroclastic rock. Individual blocks can exhibit cross- or graded bedding. Quartz and alkali feldspar are its dominant minerals.

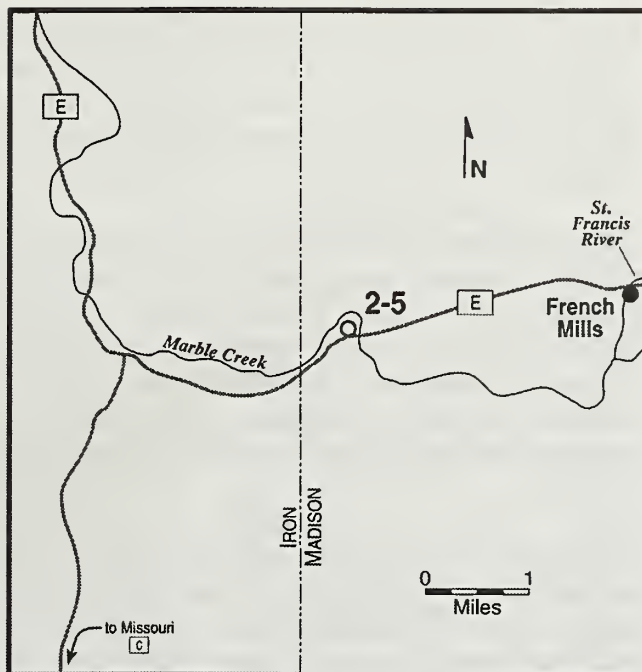


Figure 1-9. Location of Stop 2-5.

Stop 3-1: The Volcanic Stratigraphy at Johnson Shut-Ins

Location Johnson Shut-Ins 7.5-minute Quadrangle (fig. 1-10). Turn south on MO N from MO 21 just east of Graniteville. Continue on N south for 12.8 mi, turning left into Johnson Shut-Ins State Park just before the intersection with MO MM. Follow signs for office/store, and park in the large lot below the cemetery, a distance of about 0.8 mi from the park entrance. Walk along the paved path and boardwalk to the first scenic overlook. To see the entire section, continue along the lower portion of the Shut-Ins trail about 0.8–1.0 mi to the large bend in the river (where water flow changes from southwest to southeast). Walk to the river and follow it (where possible) back north to the scenic overlook. If necessary, circle larger, cliff-forming outcrops by returning back to the Shut-Ins trail, backtracking, and looping back to the river. The Cope Hollow Formation is only exposed on the east side of the river, and some underlying units have better exposures on this same side. During low water conditions, the eastern side of the river can generally be safely reached by crossing the rocks below the first

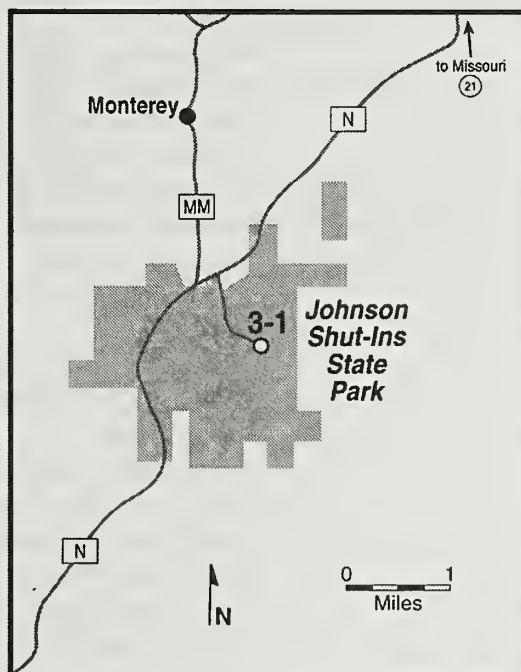


Figure 1-10. Location of Stop 3-1.

scenic overlook (i.e., the Upper Ash-Flow Tuff). However, these rocks are highly polished, so cross them with caution. The east side of the river can also be accessed by bridge by following the Taum Sauk and Ozark trails northeastward from the parking area. However, one must then do a bit of trailblazing to the southeast to reach the Shut-Ins. During any trailblazing in the park, one should be courteous to both fauna and flora, particularly snakes and poison ivy.

Outcrop Description Beautifully exposed along the East Fork of the Black River are 650 m of volcanic rocks and volcanoclastics. This spectacular section is believed to be the youngest sequence of volcanics exposed in the St. Francois Mountains (Table 1-1; Sides et al., 1981). The rocks dip about 15°–20° to the north/northeast and strike approximately normal to the valley. These rocks have been described in detail by Blades and Bickford (1976), Blades-Zeller (1980), Hebrank and Kisvarsanyi (1987), and Pippin (1996). Here we provide only brief descriptions taken from these sources. Relevant geologic maps and stratigraphic columns are shown in figures 1-11, 1-12, and 1-13.

The lowermost unit in the section is the Taum Sauk Rhyolite, the climactic ash-flow deposit in the western St. Francois Mountains (e.g., Sides et al., 1981). It is a maroon ash-flow tuff with approximately 30% alkali feldspar phenocrysts. Overlying the Taum Sauk Rhyolite is the Proffitt Mountain Ignimbrite, a lavender ash-flow tuff with about 25% phenocrysts of alkali feldspar and quartz. Above the Proffitt Mountain are a series of volcanoclastic units, collectively referred to as

Table 1-1: Partial stratigraphy of Volcanic Rocks in the St. Francois Mountains from Sides et al. (1981) and Brown (1983).

Proposed Stratigraphy	Thickness, m
Cope Hollow Formation	42
Johnson Shut-Ins rhyolite	55
Proffit Mountain Formation	138
Taum Sauk rhyolite	>1,000
Royal Gorge rhyolite	0–700
Bell Mountain rhyolite	25
Wildcat Mountain rhyolite	90
Lindsey Mountain rhyolite	500–700
Ironton rhyolite	340
Buck Mountain Shut-Ins Formation	80–1,000
Pond Ridge rhyolite	130
Cedar Bluff rhyolite	580
Shepherd Mountain rhyolite	600
Unit 690	>610
Ironton Hollow rhyolite	>130
Wolf Mountain ignimbrite	160
Tribby breccia	200
Iron Mountain Lake felsite	300
Grassy Mountain ignimbrite	–1,000
Lake Killarney Formation	>390
Upper Campground tuff	??
Marble Creek lavas	??
Lower Campground tuff	35
Crane Pond tuff/Tile Red tuff	60

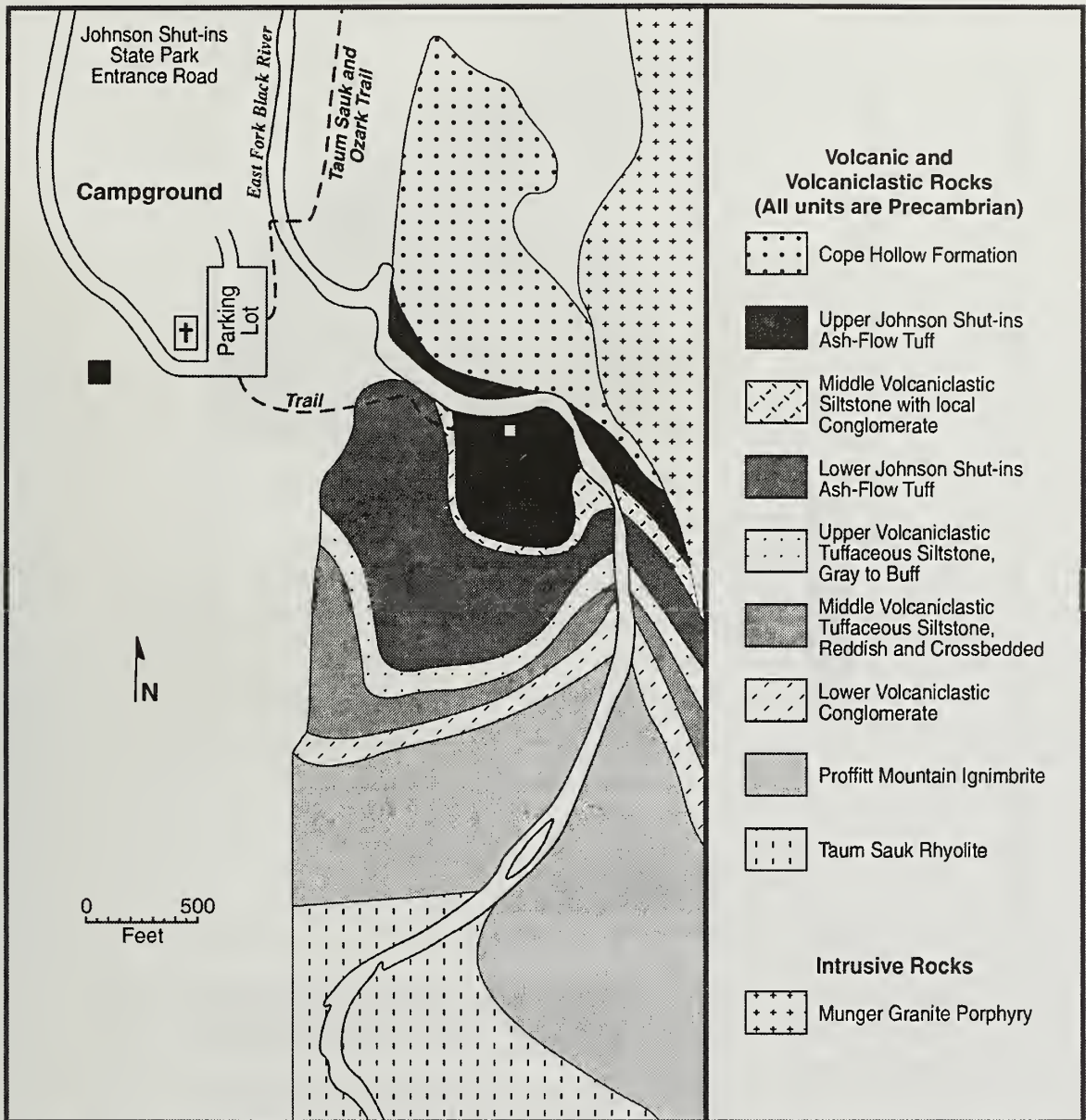


Figure 1-11. Geologic map and stratigraphy of the Johnson Shut-Ins area after Blades and Bickford (1976) and Hebrank and Kisvarsanyi (1987).

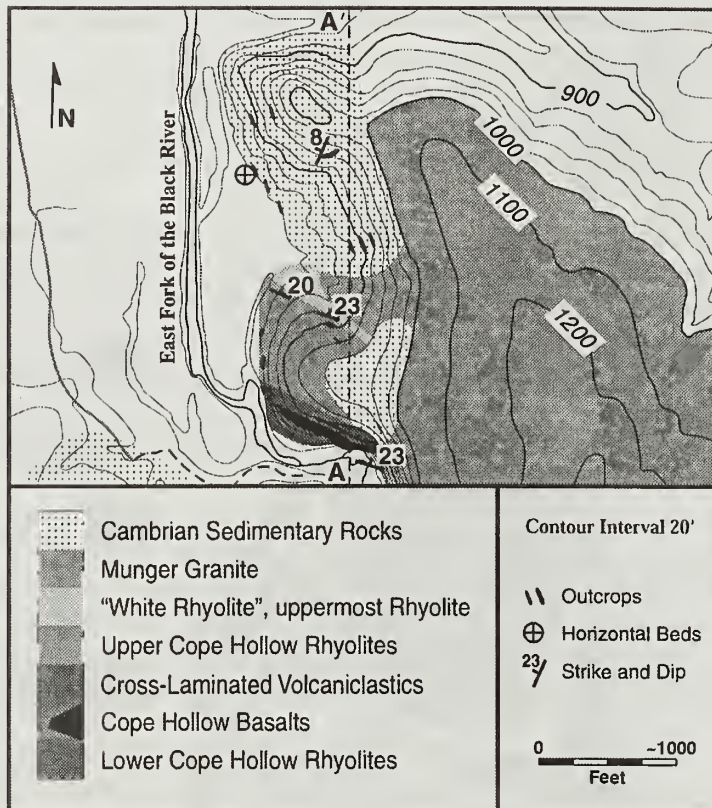


Figure 1-12. Geologic map of the northern part of Johnson Shut-Ins from Pippin (1986).

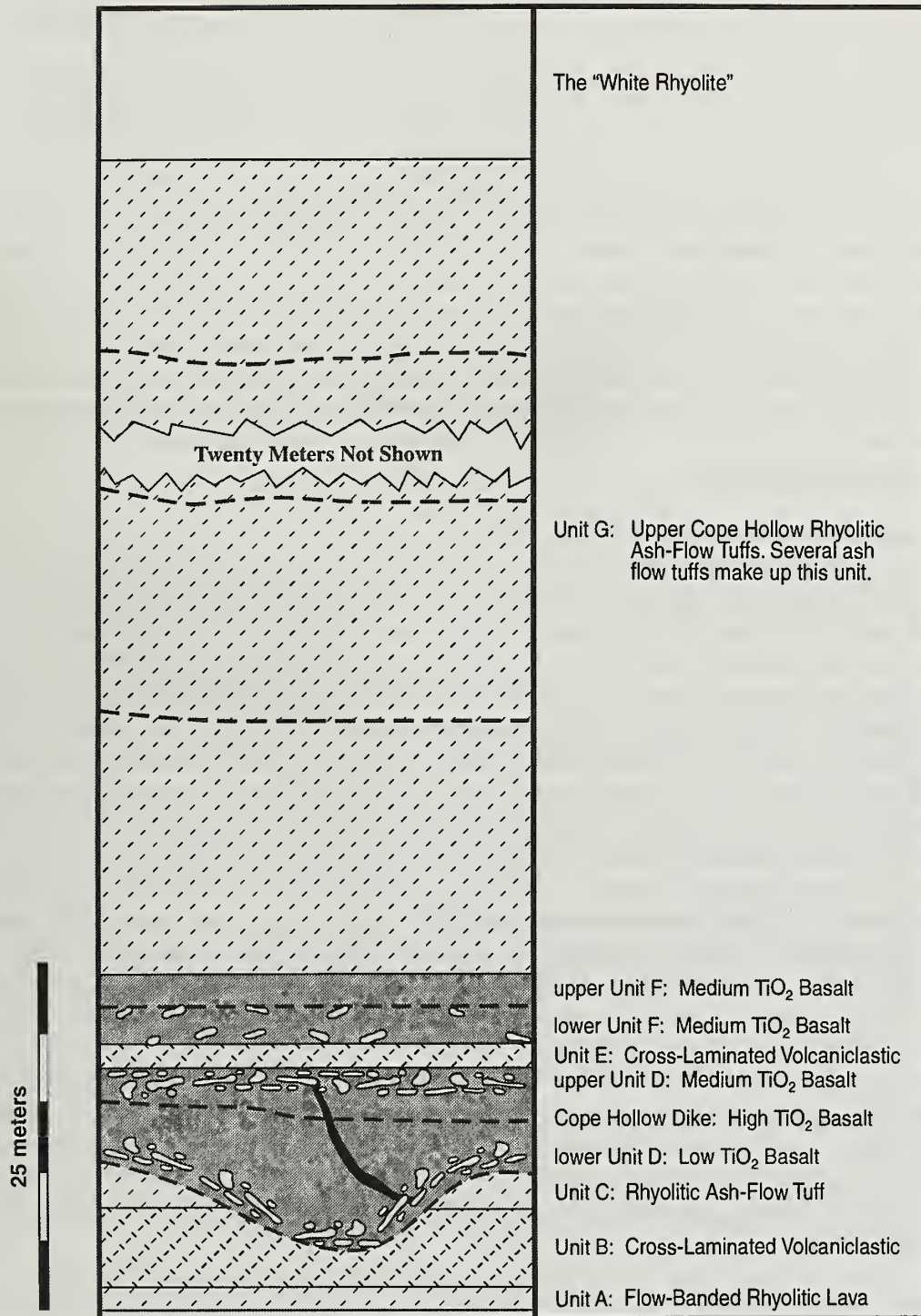


Figure 1-13. General stratigraphy of the Cope Hollow Formation from Pippin (1986).

the Lower Swimming-Hole Section by Blades and Bickford (1976) and Blades-Zeller (1980). The lowermost unit is a distinctive conglomerate with clasts of ash-flow tuff. The two overlying volcanoclastics are finer grained: a lower reddish siltstone and an upper gray to buff-colored siltstone. Overlying the volcanoclastics is the cliff-forming Lower Johnson Shut-Ins Ash-Flow Tuff. This ash-flow deposit is 16–20 m thick, is generally brick red, and has distinctive zones of accretionary lapilli and lithophysae (Blades-Zeller, 1980). Blades-Zeller (1980) also subdivided this ash flow into two flow units; they were deposited by separate pyroclastic flows (e.g., Freundt and Bursik, 1998), which cooled as a single entity. Another sequence of volcanoclastic rocks overlies the Lower Ash-Flow Tuff. These have been lumped together as the Middle Volcanoclastic Unit (Blades and Bickford, 1976; Blades-Zeller, 1980) and consist of a basal conglomerate and an overlying laminated siltstone. Capping the sequence on the west side of the river is the Upper Johnson Shut-Ins Ash-Flow Tuff. This pyroclastic flow deposit is about 17 m thick and may also consist of two flow units that cooled as one (Blades-Zeller, 1980). It is dark gray and has well-developed fiamme and lithophysae. Blades-Zeller (1980) also described a basal zone containing accretionary lapilli.

Volcanic rocks above the Lower Ash-Flow Tuff are exposed on the hillsides on the east side of the river, north of the scenic overlook (figs. 1-11 and 1-12). This section has been informally called the Cope Hollow Formation by Hebrank and Kisvarsanyi (1987) and Pippin (1996). Pippin (1996) has presented a revised stratigraphy for this formation (fig. 1-13). The contact between the Upper Johnson Shut-Ins Ash-Flow Tuff and the basal unit of the Cope Hollow Formation (Unit A) can be seen during times of low water in the eastern side of the river channel opposite the scenic overlook. Pippin (1996) suggested that the basal unit is a rhyolitic lava flow. This unit, however, bears a passing resemblance to underlying siltstones on the west side of the river. This unit is overlain by a fine-grained cross-laminated volcanoclastic rock (siltstone?), which Blades and Bickford (1976) called a water-laid tuff. Above this unit are a series of basaltic lavas, separated by another volcanoclastic unit (Unit E) and cut by a fine-grained dike. The basalts are chemically distinguishable (Pippin, 1996). They all belong to the Silvermines mafic group of Sylvester (1984). The dike, however, has distinctly higher TiO_2 and belongs to the Skrainka mafic group (Sylvester, 1984). Above the basalts are a series of poorly exposed rhyolitic ash-flow tuffs (Unit G) capped by a distinctive white to buff rhyolite whose matrix displays well-preserved ghost shards. Cambrian sediments unconformably overlie the white rhyolite (Pippin, 1996).

The volcanic section in Johnson Shut-Ins is cut by a small pluton, the Munger Granite (figs. 1-11 and 1-12). Like the Graniteville granite, the Munger has yielded a substantially younger U-Pb zircon age, $1,378 \pm 06$ Ma, than other dated igneous rocks in the St. Francois Mountains (Van Schmus et al., 1996). The Munger Granite has a distinctive orange-buff color. It is porphyritic with phenocrysts of quartz, perthite, and plagioclase (Sides et al., 1981). In places, the Munger is extensively altered.

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Quaternary and Environmental Geology of the St. Louis Metro East Area

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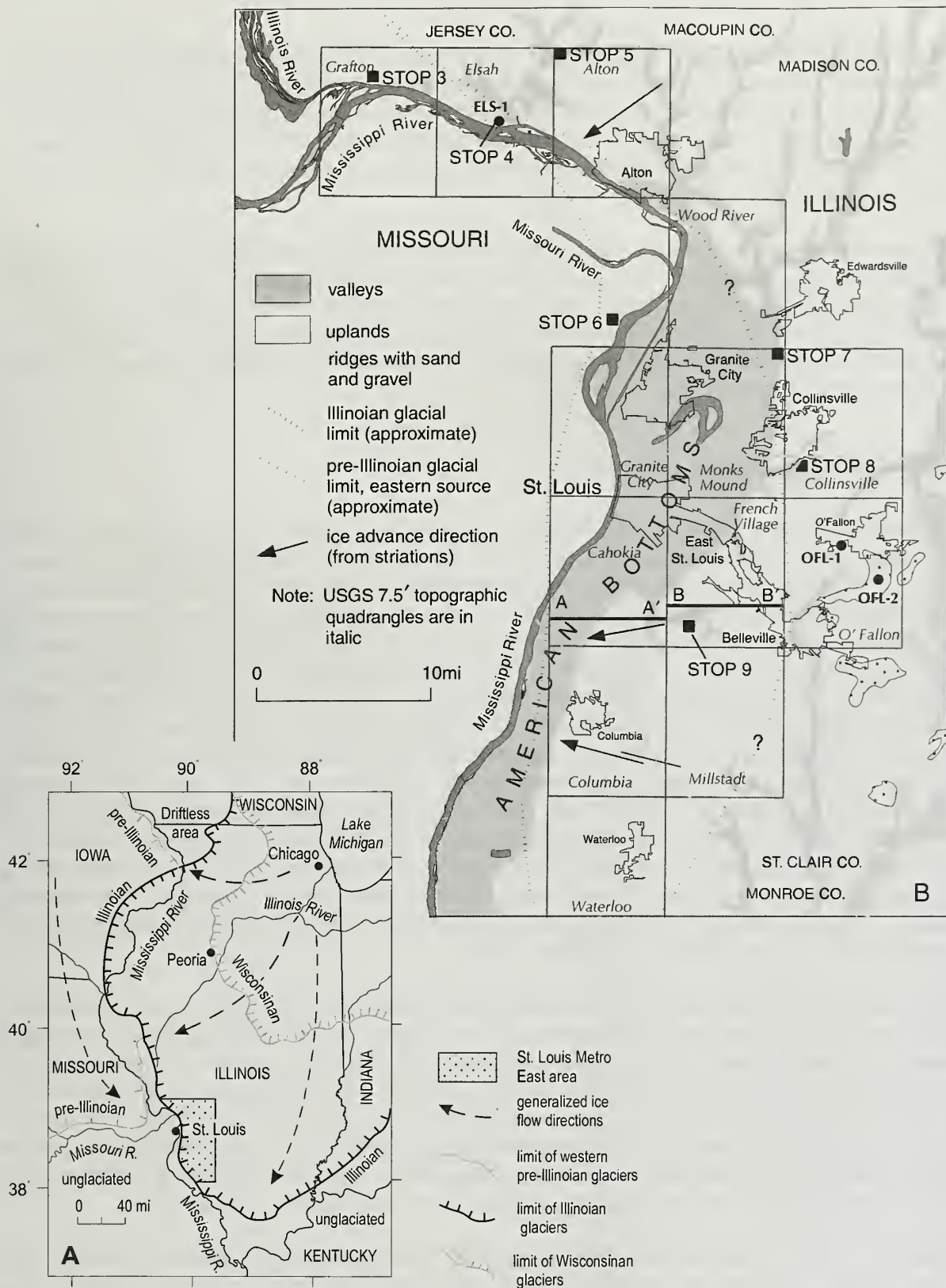
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INTRODUCTION

This field trip highlights some recently discovered sites in the St. Louis Metro East area (fig. 2-1), particularly from the Jerseyville area southward to Alton, Collinsville, and Belleville, where much new work has been done to map the surficial geology and for general research. Sites have been chosen to illustrate representative or unusual aspects of local Quaternary deposits. Some of the localities have been intensively studied (e.g., Keller Farm), whereas others are new (e.g., Dunn Road Section) but equally important for tying together the regional geologic history of the area. Most sites feature Wisconsinan loessal deposits and a variety of glacial deposits of the Illinoian Stage. The character of the loess changes within the Metro East area in response to paleowind direction, valley width, and valley orientation. The texture and composition of the till also varies, reflecting glacial entrainment, substrate lithology, and ice flow direction. Several sites, many of which are proximal to major river valleys, display thin flood beds or thicker lacustrine or alluvial deposits related to much higher base levels and sediment loads in the American Bottoms during the last two glaciations. We also discuss how knowledge of the surficial geology is a key to solving some of the pressing societal issues, such as soil erosion, groundwater supply and contamination, mass wasting, resource availability, and wetland remediation. The thickness, distribution, and character of the Quaternary deposits are extremely relevant to societal problems, and basic research on their origin is also important for devising realistic solutions to those problems.

REGIONAL QUATERNARY GEOLOGY BACKGROUND

The St. Louis Metro East area (fig. 2-2A) provides an important setting for the study of Quaternary geology because the region includes the confluence of three major rivers (Mississippi, Illinois, and Missouri Rivers) and the margins of two major glaciations (Illinoian and pre-Illinoian). This advantageous position allowed for a rich record of Quaternary deposits, contrasting in age, lithology, source, and depositional environment. One of the unique aspects of the area is the dominance of loessal and other silt deposits, which mainly originated from the broad Mississippi and Missouri Valleys that drained the entire Upper Midwest and Great Plains during the last several glaciations. The interspersal of loessal deposits among primary glacial deposits (till and sorted sediments) on uplands allowed for excellent preservation and separation of many key litho- and pedostratigraphic units. The combination of thick loess deposits with generally non-erosive glacial deposition near the terminal margin of the Laurentide Ice Sheet was fortuitous, since this



combination allowed for better preservation of easily recognizable and traceable layers in the geologic record. Furthermore, the wide expanse of post-glacial floodplain in the American Bottoms area (fig. 2-2B) contains within it an abundance of archeological sites (Milner, 1998) and a high-quality geologic record of the Midcontinent during the late Holocene. Thus, St. Louis Metro East area Quaternary deposits may reveal clues as to the paleoclimate and paleoenvironment of the past 500,000 years.

Because of its societal planning needs as a growing metropolis, the St. Louis Metro East area has been the focus of several 7.5-minute quadrangle geologic mapping projects by the Illinois State Geological Survey (ISGS) in the last few years (partially funded by the U.S. Geological Survey STATEMAP program). Although the geology and geomorphology of the region have been examined by several previous researchers, many new findings were discovered during the surficial geologic mapping in the area.

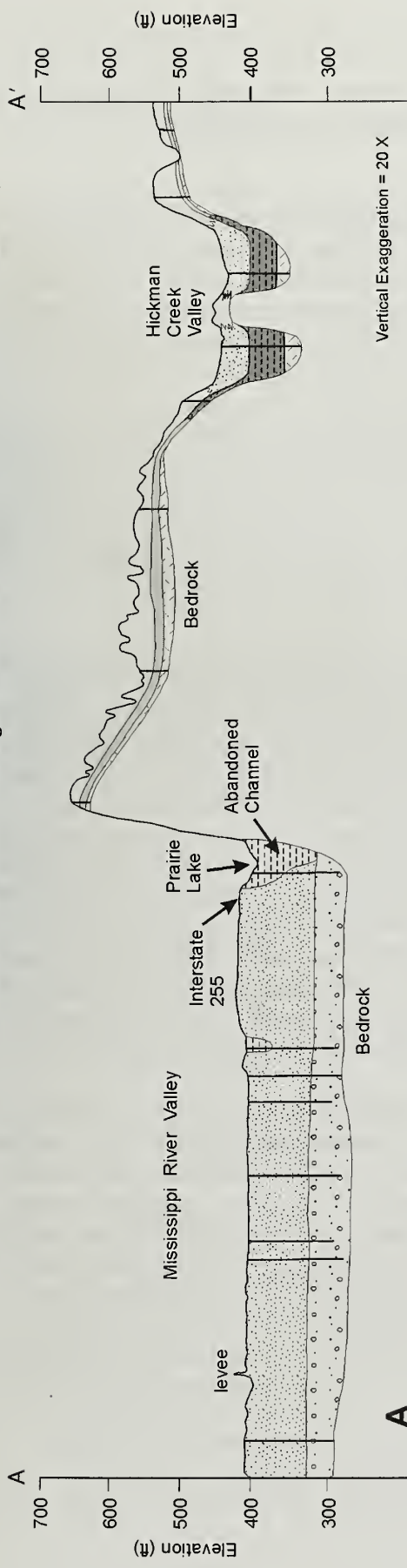
Background and Data Sources

American Bottoms The American Bottoms, an extensive floodplain of the Mississippi River that contains many lakes and swamps, lies mainly on the Illinois side of the Mississippi River (fig. 2-2B). Physiographic divisions in the American Bottoms have been noted by Yarborough (1974); Hajic (1990, 1993) described landform sediment assemblages in the northern portion of the American Bottoms and the lower Illinois Valley. The environmental setting and geomorphology of the Mississippi River floodplain were discussed by Gladfelter (1979) and White et al. (1984). Milner (1998) reconstructed some of the former paths of the Mississippi River in historical and late Holocene times. Abundant data on shallow materials (typically down to 5 to 15 ft deep) are available from archeological projects along interstate routes (Kolb, 1997; Booth and Koldehoff, 1999) and soil survey parent material data (Fehrenbacher and Downey, 1966; Wallace, 1978; Goddard and Sabata, 1982; Higgins, 1984) that reflect sediments to depths of about 3–5 ft. The Illinois Department of Transportation, U.S. Army Corps of Engineers (Smith and Smith, 1984), and many consulting companies in the area (e.g., Philip Services Corp., Geotechnology Inc., and Shively Geotechnical Inc.) have contributed to data from deep borings. Groundwater resources and environmental contamination in the American Bottoms were investigated by Bergstrom and Walker (1956) and Rehfeldt (1992).

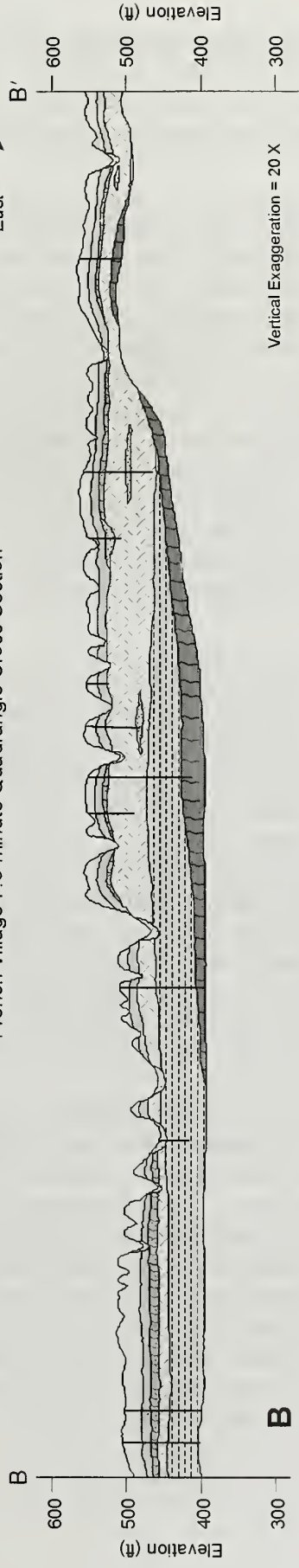
Upland Areas Much of the early work in the area on the surficial geology of the uplands was summarized on a regional scale by Willman and Frye (1970). The Wisconsinan loess stratigraphy of the region was studied in detail by McKay (1977), with emphasis on the carbonate mineralogy, and by Grimley (1996) and Grimley et al. (1998), with emphasis on magnetic properties and silt mineralogy. McKay (1979b) also provided a stratigraphic framework for Illinoian and pre-Illinoian deposits in the St. Louis Metro East area. In other thesis research projects, Bratton (1971) studied selected Wisconsinan deposits in Madison and St. Clair Counties, and Odom (1958) mapped the bedrock and surficial geology in a portion of the Cahokia Quadrangle.

A series of 1:125,000 maps for societal planning in St. Clair County was published by Jacobs (1971). Ongoing mapping of surficial geology and bedrock is occurring in the entire St. Louis Metro East area (in Illinois) at a 1:24,000 scale (fig. 2-2B). To date, surficial geology maps are available for the Grafton and Alton 7.5-minute Quadrangles (Grimley, 1999a, b). The stops on this field trip will be primarily in the Alton, French Village, Cahokia, Columbia, and Waterloo 7.5-minute Quadrangles, all of which have been or are currently being mapped (fig. 2-3).

Cahokia 7.5-minute Quadrangle Cross Section



French Village 7.5-minute Quadrangle Cross Section



- | | | | | | |
|--|---------------------------------------|--|--|--|--|
| | Cahokia Fm., clayey alluvium | | Peoria Silt, loess | | Glasford Fm., sand and gravel |
| | Cahokia Fm., sandy and silty alluvium | | Roxana Silt, loess | | Petersburg Silt, lacustrine |
| | Henry Fm., outwash | | Berry Clay, weathered till and colluvium | | Lierle Clay, weathered till and alluvium |
| | Equality Fm., lacustrine | | Glasford Fm., till | | |

Figure 2-3. East-west cross sections of Quaternary deposits across the (A) Cahokia 7.5-minute (A-A') and (B) French Village 7.5-minute (B-B') Quadrangles (see fig. 2-2 for cross section lines).

Quaternary Deposits and Environments

The following discussion, organized from oldest to youngest units, is based on the literature as well as recent and ongoing geologic mapping in the St. Louis Metro East area.

Residuum Silty clay loam to clay residuum (0 to 20 ft thick) is found lying on the bedrock in many areas. Particularly common in unglaciated areas or areas of thin till, the residuum is generally thickest above limestone bedrock and is mainly weathered bedrock with some admixed loessal material. This type of material was informally classified by Nelson et al. (1991) in southern Illinois (Pope County) as the Oak formation. Similar material in northwestern Illinois was interpreted to have been weathered mainly during the Tertiary and early Quaternary (Willman et al., 1989).

Pre-Yarmouthian Deposits Till, alluvium, loess, and lacustrine sediments are common pre-Illinoian deposits in southwestern Illinois. Pre-Illinoian deposits in the Metro East area are restricted to present-day upland areas, but are preserved mainly in buried valleys east of the Illinoian ice margin (e.g., fig. 2-3). As noted by recent mapping, the limit of pre-Illinoian glaciers is interpreted as being similar to that delimited on a statewide scale by Willman and Frye (1970). Pre-Illinoian deposits in Illinois may be correlative with oxygen isotope stage 12, a period of substantial global ice volume about 450,000 years ago (Imbrie et al., 1984).

Pre-Illinoian till in this area, known as the Banner Formation (Willman and Frye, 1970), has not been definitively found west of a curved line extending from Alton to Belleville to southeast of Waterloo (fig. 2-2B). In the Alton and Elsah 7.5-minute Quadrangles, the Banner Formation is patchy and tends to be preserved mainly in bedrock lowlands or depressions (Grimley, 1999b). Although nonexistent over much of the landscape, the Banner Formation, where present, can be thicker than younger Illinoian till deposits. In core OFL-1 of the O'Fallon Quadrangle (fig. 2-2B), pre-Illinoian till is a silt loam diamicton up to about 30 ft thick that overlies lacustrine/loessal silts (Harkness Silt), which are locally preserved beneath the pre-Illinoian till. In unoxidized, calcareous till of core OFL-1, the relative abundances of clay minerals average 25% expandables, 41% illite, and 34% kaolinite plus chlorite. The comparatively high kaolinite-chlorite percentage and the shape of the x-ray diffraction traces suggest a great degree of local bedrock influence, perhaps by disaggregation of shale fragments into the clay fraction (H. D. Glass, ISGS, 1999, personal communication). Grain size distribution of till in this core (<2-mm fraction) averages 20% sand, 55% silt, and 25% clay, which is fairly typical for pre-Illinoian till in the region (McKay, 1979b).

Pre-Illinoian ice in the St. Louis Metro East area likely originated from the east or northeast (Willman and Frye, 1970). Despite its proximity, a western source of glacial ice is unlikely because Calhoun County, Illinois, and western portions of St. Louis, Missouri, remained unglaciated (fig. 2-2A). Scattered striations, found underneath probable pre-Illinoian till, indicated ice flow from the northeast to east-northeast direction (Grimley, 1999b). The composition of the Banner Formation in this area mainly reflects the local substrate, including highly erodible Pennsylvanian bedrock, residuum, and proglacial silt, which were incorporated into the basal debris zone of glaciers. Low percentages of expandable clay minerals in unaltered till in core OFL-1 also suggest an eastern rather than a western source. Western source, pre-Illinoian tills in southeastern Iowa and western Illinois (Wolf Creek Formation) are known to have expandable clay mineral contents greater than 50% (Hallberg et al., 1980).

Fine-grained alluvium was also deposited and preserved in some areas, primarily to the west of the pre-Illinoian glacial limit, such as in the French Village Quadrangle (Grimley and McKay, unpublished map). Sand and gravel of pre-Illinoian Stage, as yet, have not been found in the Metro East area; perhaps these deposits were removed during stream incision of the succeeding Yarmouthian Stage.

Yarmouthian Deposits and Soil Development Materials deposited during Yarmouthian time include alluvial and lacustrine silt, silty clay, and clay. These interglacial deposits, classified as the Lierle Clay Member of the Banner Formation (Willman and Frye, 1970), are typically leached and altered by the strongly developed Yarmouth Geosol and can be up to about 20 ft thick in former depressional or alluvial areas (fig. 2-3B). The Yarmouth Geosol developed during and subsequent to Lierle Clay deposition, yielding upwardly growing (cumulic) overthickened soil profiles.

The Yarmouthian Stage may have been of sufficient duration (about 240,000 years?) to have included several warm and cold Milankovitch cycles, perhaps oxygen isotope stages 7 through 11 (Grimley, 1996). Ice advances possibly may have occurred in the northern Great Lakes such that loess deposits may have accumulated in the Metro East area during parts of Yarmouthian time. The evidence for this supposition is that the upper solum of the Yarmouth Geosol (developed in Lierle Clay) is typically overthickened and gradational with the overlying Illinoian silts. Overthickening and gradational contacts may have been the result of slow deposition of loess.

Data from marine oxygen isotope stages 11 and 5 (probably the warmest periods of the Yarmouthian and Sangamonian Stages, respectively) suggest a climate fairly similar to that of the Holocene (Droxler and Farrell, 2000; Hodell et al., 2000). Although the older interglacial intervals may have been slightly warmer at times (Rousseau, 1999), the most significant difference among the interglacial periods was more likely one of duration rather than climate.

Illinoian Deposits Illinoian deposits are more widespread than the older Quaternary deposits. Almost all of the Metro East area was glaciated during the Illinoian Stage (fig. 2-2), leaving behind an assortment of intercalated till, lacustrine, loessal, and outwash deposits. These deposits were likely laid down during oxygen isotope stage 6 (Curry and Pavich, 1996; Curry and Baker, 2000), between about 190,000 and 130,000 years ago. Regional indications are that glacial ice advanced from the Lake Michigan basin during the Illinoian Stage (Willman and Frye, 1970) and spread almost completely across Illinois (fig. 2-3A). Striations and hairpin erosion marks on the limestone bedrock at Lohr Quarry (northwest of Alton) confirm ice flow advance from the northeast to east-northeast direction in the Alton area (Grimley, 1999b). In the Columbia and Dupon areas, striations on sandstone and limestone are aligned more east-west and are attributed to ice flow from the east (fig. 2-3B).

Several new findings in outcrops and cores indicate that early Illinoian loess and lacustrine sediment (Petersburg Silt) are more extensive than previously thought (fig. 2-3B). Although occurrences of waterlaid and windblown silts beneath Illinoian till were noted at such localities as Hickman Creek (Odom, 1958), Powdermill Creek (McKay, 1979b), and a bluffside quarry near Alton (Willman and Frye, 1958), the widespread occurrence of these deposits was not fully realized. The Petersburg Silt, predominantly of lacustrine origin, can be up to 60 ft thick in some buried valleys that are tributary to the Mississippi Valley (fig. 2-3B). Much of the Petersburg Silt, which is generally crudely bedded and contains numerous *Picea* logs and fragments, was deposited by backwaters in tributary valleys to the Mississippi River valley. Slow-moving backwaters (slackwater lakes) originated as a result of rapid sedimentation and aggradation of the Mississippi

River to a level above the tributary mouths. This aggradation likely resulted from sediment-laden meltwater originating farther upstate in Illinois and in the Upper Mississippi River drainage area. At several localities, the Petersburg Silt contains primarily an aquatic gastropod fauna, which confirms a shallow water environmental interpretation. Some terrestrial shells, wood fragments, and much loess were redeposited from upland areas into the shallow lakes. Climatic conditions were likely fully glacial, based on the fossil evidence, the presence of dropstones with Canadian shield lithologies, and the occurrence of Illinoian till immediately above the Petersburg Silt without an intervening paleosol. In some areas at higher elevations (generally above 480 ft), the Petersburg Silt is loessal in origin or is a mixture of loessal and lacustrine silts. Amino acid (alloisoleucene/isoleucine) epimerization ratios from gastropods in the Petersburg Silt are characteristically Illinoian; values generally have been between 0.15 and 0.26 at the Powdermill Creek Section (Miller et al., 1994) and other sites in the Metro East area (see Oches, this volume).

An older silt deposit occurs discontinuously below the Petersburg Silt and above the Yarmouth Geosol. This unnamed leached silt (less than 5 ft thick) has only been observed in a few localities in Greene and Madison Counties (unpublished studies) but may be correlative to the Chinatown Silt of McKay (1979b) at the Maryville Section. This silt was probably deposited during late Yarmouthian or very early Illinoian time. To avoid confusion, the Chinatown Silt name is not used here because the Chinatown Silt at the Powdermill Creek Section west of Belleville (McKay, 1979b; Miller et al., 1994) is now thought to be equivalent to the Petersburg Silt.

Illinoian till and ice margin sediments (Glasford Formation) are common throughout the Metro East vicinity. The texture of Glasford Formation diamicton ranges from loam to silt loam to silty clay loam. Diamicton is generally sandier to the northeast, clayier to the southwest, and siltier to the west. Thick residual clay soils on limestones in Monroe County probably contribute to a more clay-rich till in this area. The increasing silt content to the west is undoubtedly a result of incorporation of loess and lacustrine silt by ice movement in that direction, as involutions of silt are commonly seen in the field at the base of the Glasford till. Some laboratory data from the Glasford till indicate a silty basal zone with greater amounts of expandable clay minerals.

Sand-filled channels are present in some places within the Glasford Formation. They occur primarily in the upper portion of the unit, but locally they are distributed throughout (fig. 2-3B) or occur as R-channels at the base of the unit (some of these sand bodies are present at the Prairie du Pont Section). Large ridges, containing sand and gravel and diamicton (all Hagarstown Member, Glasford Formation), occur in eastern Madison and St. Clair Counties. Based upon a boring drilled in the O'Fallon Quadrangle near Shiloh (OFL-2; fig. 2-3B), the loess-covered ridges are mainly composed of stratified sands (about 40 ft thick) that are intercalated with and underlain by diamicton (greater than 50 ft thick). The longest part of the ridge at Shiloh trends west-southwest, likely parallel to ice flow, based on a model for the formation of these ridges in Illinois (Jacobs and Lineback, 1969). The formation of the Shiloh ridge may have been influenced by a bedrock low that occurs under the ridge; any explanation for its origin must account for the inversion of topography. The Hagarstown "ridged-drift" may have formed as a result of enhanced deposition of mud flows and sands into a former low, in crevasses, or in channels beneath the ice (Jacobs and Lineback, 1969), or may be related to ice-contact debris from an ice lobe reentrant.

Terraces of sand and gravel (Pearl Formation), overlain by loess, occur along some valleys. Nonetheless, Pearl Formation sand and gravel (excluding the Hagarstown ridges) is less common than would be expected for an area near the margin of a major glaciation. Much of the outwash that was originally deposited must have been eroded during the succeeding interglacial

(Sangamonian Stage) when large-scale stream incision occurred. Recently, sand and gravels have been observed above and below Illinoian till proximal to Cahokia Creek Valley.

Loess and lacustrine silt (Teneriffe Silt) blanketed both Glasford and Pearl Formation deposits following ice retreat to the northeast. These late-Illinoian silts are normally 3 to 10 ft thick and are typically a yellow-brown to gray silt loam to silty clay loam with relatively scarce sand and pebbles. These silts were commonly the parent material for the Sangamon Geosol and so are typically weathered throughout their thickness.

Sangamonian Deposits and Soil Development The last interglacial warm period (known as the Sangamonian Stage), although of considerable duration (Curry and Baker, 2000), largely resulted in a record of soil formation (Sangamon Geosol) rather than extensive deposits. The Sangamonian interglacial age lasted about 75,000 years (Curry and Baker, 2000), which was not nearly as long as the Yarmouthian interglacial, based on physical, mineralogical, and elemental indicators of soil development (Willman and Frye, 1970; Grimley, 1996). The soil solum of the Sangamon Geosol is generally not as thick as the Yarmouth Geosol solum, yet is thicker than the solum of modern soil. However, whereas the Yarmouth Geosol has been stripped or truncated in many places by succeeding Illinoian glacial erosion, the Sangamon Geosol is typically well preserved because of non-erosive burial by a blanket of Wisconsinan loess.

Where present, Sangamonian deposits are mainly alluvial, lacustrine, or accretionary. Primarily silty clay loam to silty clay deposits, with sparse pebbles, these deposits have been referred to as the Berry Clay Member of the Glasford Formation (Willman and Frye, 1970). The Berry Clay, generally less than 10 ft thick, is mainly found in areas that were formerly flat-lying or depressional areas on the landscape where slopewash was deposited and shallow lakes may have remained during the interglacial interval. Because the Berry Clay and Teneriffe Silt were both altered by later Sangamonian weathering, they are commonly difficult to differentiate.

Based on ostracode and pollen studies in south-central Illinois, climatic conditions during the Sangamonian Stage were probably fairly similar to those of today, except that winters may have been slightly warmer during portions of Sangamonian time (Curry and Baker, 2000).

Wisconsinan Deposits Although glacial ice did not reach southwestern Illinois during the last glaciation, loess, outwash, dunes, and lake sediment resulted from glaciation in the Upper Mississippi River drainage basin. Glacial ice in Illinois advanced to within about 80 miles of the St. Louis Metro East area; however, most of the outwash in the American Bottoms and related loess deposits were probably from Upper Mississippi and Missouri Valley sources, according to mineralogical compositions (Glass et al., 1968; Grimley, 2000).

Outwash sand and gravel (Henry Formation) is up to 50 ft thick in the deepest portions of the American Bottoms (Bergstrom and Walker, 1956; Grimley and McKay, unpublished map), where it overlies bedrock (fig. 2-3A). The Henry Formation was deposited in a braided channel system as the river aggraded in response to glaciation in the Upper Midwest. At two or three operating pits in the American Bottoms, coarse sand with some gravel is currently being dredged, mainly for construction use, from a depth of about 60 to 100 ft. Illinoian and pre-Illinoian outwash may exist in the American Bottoms, but these deposits would be extremely difficult to distinguish from younger outwash. The available evidence suggests that much of the older outwash has been scoured away. In addition to being a local material resource, the Henry Formation is also a significant

groundwater resource (Bergstrom and Walker, 1956). However, in recent years, extensive contamination of this aquifer has been a significant problem (Rehfeldt, 1992).

Loess deposits, deflated from the huge expanse of floodplain in the American Bottoms, are up to 100 ft thick on some upland bluffs near Collinsville, but thin exponentially to about 20 ft thick towards the eastern portion of the Metro East area (fig. 2-4; McKay, 1977). Loess deposits are somewhat thinner near Alton and Columbia, ranging from 15 to 40 ft thick (Grimley, 1999b), because steep bedrock bluffs may have restricted loess deflation from the valley. Additionally, valley orientation is parallel to the prevailing westerly winds near Alton, and a more narrow valley exists near Columbia. Wisconsin loess deposits have been classified as two major formations, Peoria Silt and Roxana Silt (Willman and Frye, 1970). The older Roxana Silt, a pinkish brown to pinkish gray silt loam, was deposited between about 55,000 and 28,000 ^{14}C yr B.P. (before present) (McKay, 1977, 1979b; Hansel and Johnson, 1996). The Peoria Silt, the younger and normally thicker unit (fig. 2-4), is a yellow-brown to gray silt loam that was deposited between about 25,000 and 12,000 ^{14}C yr B.P. (McKay, 1977, 1979b; Hansel and Johnson, 1996; Grimley et al., 1998). Loess deposits are thick enough in the more northern Metro East areas (near Collinsville) that the eastern bluffs bordering the American Bottoms are composed entirely of loess with till and bedrock lying at depths below the level of the present floodplain. On upland areas, loess deposits generally blanket the landscape because of their deposition by atmospheric settling. Yet, loess deposits have commonly been eroded along steep ravines and valleys, thus exposing the underlying till, lake deposits, residuum, or bedrock.

Lacustrine deposits are fairly commonly preserved in terraces of tributary creeks to the Mississippi Valley. Fine sands, silts, and silty clays (Equality Formation) have been noted in tributary valleys, such as those of Piasa Creek (Elsah 7.5-minute Quadrangle, unpublished) and Hickman Creek (fig. 2-3A; Cahokia 7.5-minute Quadrangle, unpublished) within a couple of miles of their outlet to the Mississippi Valley. Lake sediment was likely deposited by backwaters of the Mississippi and Missouri Rivers that inundated tributary valleys, forming slackwater lakes during Mississippi River aggradation when outwash and loess were also being deposited. The environment and level of deposition of the Equality Formation were similar to that described for the Illinoian Petersburg Silt. Post-glacial downcutting through the lake sediments has left behind terraces in some areas. Terraces, capped by a few feet of loess and underlain by as much as 105 ft of slackwater sediment, are common at about the 470- to 480-ft elevation. These terraces probably are correlative to the Cuivre Level of the St. Charles Terrace Group in Missouri (Hajic et al., 1991). On Piasa Creek terrace core ELS-1, AMS radiocarbon ages of 29,600 \pm 700 ^{14}C yr B.P. (A-0011; shells), 42,000 \pm 3,100 ^{14}C yr B.P. (A-0010; shells), and 43,772 \pm 1,590 ^{14}C yr B.P. (A-0022; seeds) were determined from samples of pinkish brown silty clay at depths of 66 ft, 105 ft, and 107 ft, respectively. The similarity in age and color of this lower Equality Formation to that of the Roxana Silt is attributed to synchronous deposition. Gastropods (e.g., *Gyraulus*, *Amnicola*, and *Valvata tricarinata*), small bivalve shells, and ostracodes (*Candona caudata*, *Candona rawsoni*, and *Limnocythere herricki*) in the lower Equality Formation are typical of slow-moving water. The ostracode assemblage (identified by B. B. Curry, ISGS) and plant macrofossils (amaranths and chenopods; identified by R. G. Baker, University of Iowa) are indicative of a cool climate that was as dry or drier than today and similar to that in the northern Great Plains.

Holocene Deposits and Modern Soil Development Deposits of the current interglacial period (the Holocene) include alluvial fans, point-bar deposits, and abandoned meander fills in the American Bottoms as well as upland stream alluvium (fig. 2-3). All of these deposits are classified in the Cahokia Formation (Willman and Frye, 1970). Most small upland streams contain silty

alluvium because of the large amount of incision and slumping of the thick silty loess deposits that are easily eroded by water. Some of the larger river tributaries to the Mississippi River contain more sandy alluvium. In lower reaches of the larger upland tributaries, the Cahokia Formation commonly overlies Equality Formation lake deposits (fig. 2-3A).

In the American Bottoms, the Cahokia Formation consists of thick (up to 60 ft), well-sorted sandy deposits of former point bars and thick (up to 60 ft) silty clay fills in abandoned river channels and oxbow lakes (fig. 2-3A; White et al., 1984; Smith and Smith, 1984). These units overlie Henry Formation sand and gravel (fig. 2-3A). Characteristics of surficial deposits in the American Bottoms are somewhat predictable based on the geomorphology (Yarborough, 1974; Hajic, 1993) data from the U.S. Department of Agriculture soil survey maps (Goddard and Sabata, 1982; Wallace, 1978) and remote sensing data.

On stable landscapes, modern (Holocene) soil profiles have developed in the Peoria Silt on upland areas and in the Cahokia alluvium in the valleys and bottoms. Because of their younger substrate, modern soils developed in the Cahokia alluvium are much less developed (lacking a B horizon or having only a weak B horizon) than those developed into Peoria Silt on stable uplands. Of course, soils in steeply sloping areas have weaker development because of erosional processes and may contain thin layers (as much as 10 ft) of colluvium.

SITE DESCRIPTIONS:

DAY 1 (BLOOMINGTON-NORMAL TO ALTON)

Stop 1: Bloomington Area Surficial Geology (Skip Nelson)

Bloomington East 7.5-minute Quadrangle, Sec. 25, T23N, R2E, McLean County, Illinois.

The Holiday Inn and the town of Normal are located on the Normal Moraine. The Normal Moraine is a belt about 5 mi wide consisting of low ridges trending N50°W, composed of the Batestown Member of the Lemont Formation deposited during the Wisconsin glacial maximum. The unoxidized Batestown Member is a very stiff (unconfined compressive strength: Qu 200–400 kN/m), gray (7.5 YR 5/0), slightly pebbly silt loam (30% sand, 50% silt, 20% clay) diamicton with a moisture content of 11 to 15%. It is interpreted to be mainly till. Borings for the Illinois State University Arena indicate that the Batestown diamicton in the Normal Moraine is more than 80 ft (25 m) thick, about twice the thickness of Batestown diamicton behind the end moraine. The primary topography has been modified by post-depositional kettle filling, loess deposition, and soil development. Filled kettles are abundant on and behind the Normal Moraine. Kettle fill materials (sandy silt and loam) generally have moisture contents of 14 to 24% and are soft to firm (Qu 40 to 100 kN/m).

In the Bloomington area, Batestown diamicton is underlain by the Tiskilwa Formation, which is typically a stiff to hard (Qu 146–624 kN/m), slightly pinkish gray (2.5 PR 9/1), slightly pebbly loam (35% sand, 45% silt, 20% clay) diamicton with a moisture content of 8 to 17%. The Tiskilwa Formation is interpreted to be mainly till. Borings indicate that the Tiskilwa diamicton contains shears that are concave upward and to the north. At BroMen Hospital, Robein Member silt was repeated (vertical separations of 10 m) in two borings. The unconfined strength of Tiskilwa diamicton is

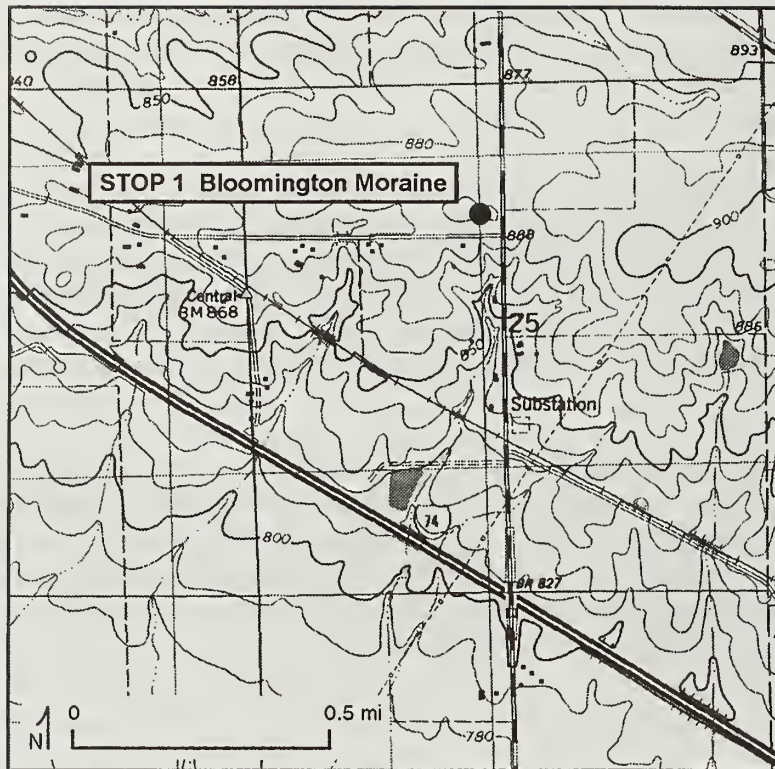


Figure 2-4. Location of Stop 1 (Bloomington Moraine) in a portion of the Bloomington East 7.5-minute Quadrangle.

bimodal; the mean unconfined strength is 270 kN/m (11–17% moisture), but almost doubles to 490 kN/m (8–14% moisture) in the 2 m adjacent to the shears. Shears have been recognized in borings and wells in the Tiskilwa Formation from Bloomington eastward to LeRoy. The Bloomington Moraine, composed of Tiskilwa diamict, is as much as 15 m higher between Bloomington and Moraine View State Park (just north of LeRoy) than east of Moraine View State Park or between Bloomington and Peoria. Stop 1, shown in figure 2-3, will be a view from the Bloomington Moraine southeast of Bloomington-Normal.

Stop 2: Kane Quarry (Grimley, Phillips, and Follmer)

Boyer Creek 7.5-minute Quadrangle, SE, NW, SW Sec. 27, T9N, R12W, Greene County, Illinois. Top elevation, 174 m (571 ft); bedrock elevation, ~ 530 ft.

Overview Kane Quarry, which contains exposures of glacial lacustrine sediment, diamict, sand-filled fractures, and loess, is located in western Illinois about 5 mi northwest of Jerseyville and about 1 mi southeast of Macoupin Creek. The limestone quarry mines Burlington/Keokuk Limestone and has an overburden thickness of about 40 ft. The described section is located on a highwall in the northeastern portion of the quarry. This highwall was excavated into an upland area of the Illinoian till plain. The top of this highwall is about 130 ft higher in elevation than Macoupin Creek valley visible to the northwest (fig. 2-5).

From the exposures viewed in 1999 and 2000, the bedrock surface underlying the upland area on the east side of the quarry appears to be relatively flat and occurs at an elevation of about 530 ft. Bedrock is also exposed up to about 530 ft along a roadcut about 0.5 mi to the southeast of the studied highwall (fig. 2-5).

Quaternary deposits consist of thin residuum and loess near the base of the exposure, overlain by Illinoian diamict, and proglacial lacustrine silt deposits, which in turn are overlain by Wisconsinan loess (fig. 2-6). The presence of the Sangamon Geosol weathered into diamict

below the loess deposits indicates an Illinoian Stage for deposits immediately below this level. The lowest few feet of un lithified deposits may be pre-Illinoian or older.

Site Details The oldest Quaternary deposit noted at the described section is the Petersburg Silt. However, about 100 ft north of the described section, a strongly developed interglacial soil was observed below the Petersburg Silt in 1999. This soil was interpreted to be the Yarmouth Geosol and was developed into loess or alluvium. This soil merges into a residual soil on the limestone bedrock.

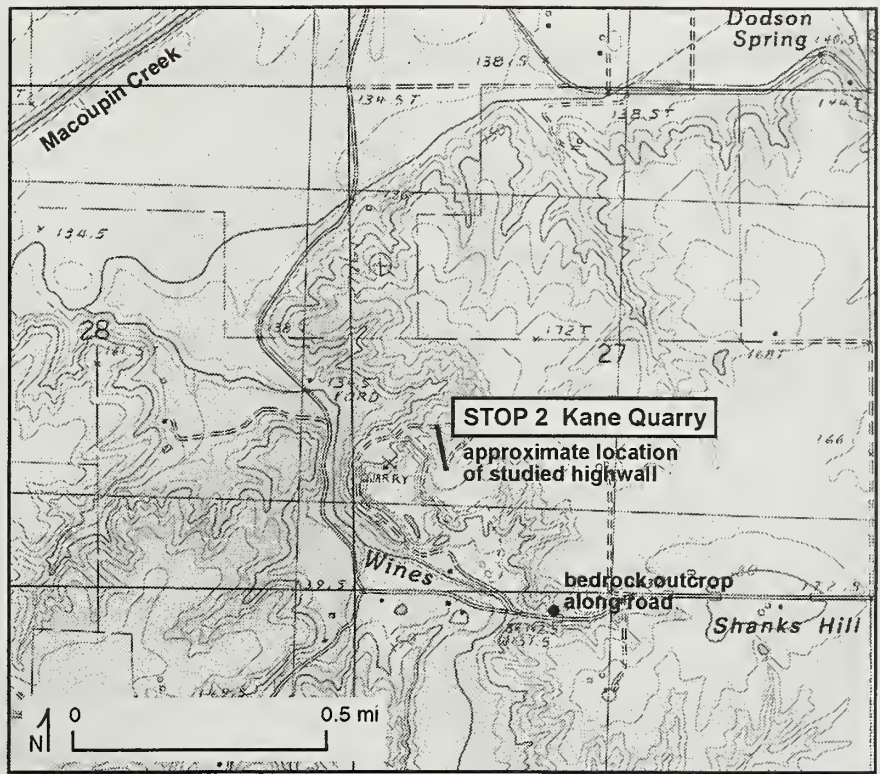


Figure 2-5. Location of Stop 2 (Kane Quarry) in a portion of the Boyer Creek 7.5-minute Quadrangle.

The Petersburg Silt, up to 2 m thick, has the loose quality and massive character of a loess deposit rather than an alluvial silt, although an alluvial component may be present. The lower half of the Petersburg Silt appears to contain a weakly developed interstadial soil. An increase in dolomite content upward may indicate an increase in the deposition rate or better preservation because of ensuing burial by glacial ice. Petersburg Silt was also found to have large magnetic susceptibility values (60×10^{-5} to 100×10^{-5} [SI units]) (fig. 2-7), which are slightly greater than typical eolian deposits in the region (Grimley, 1996). The large values for St. Petersburg Silt may be due to its provenance or to neof ormation of ultrafine ferrimagnetic minerals in paleosols.

Above the Petersburg Silt lies a dense silt loam diamicton unit that is correlated to the Glasford Formation. The lack of weathering at the contact between these units indicates a conformable sequence that was probably deposited during the glacial maximum of the Illinoian Stage. The diamicton, albeit relatively thin (about 1 m thick), is dense, calcareous, and unoxidized and contains erratic pebbles and spruce wood fragments. The diamicton is interpreted to be mostly subglacial till and correlates with the time of maximum glacial advance of the Laurentide Ice Sheet in the Midwest. Orientation of spruce wood in the till (Table 2-1) suggests an ice advance from the east or east-northeast. This theory fits well with the regional picture (fig. 2-2B), as striations in the Alton area, 15 miles to the southeast, are commonly N55°E. Magnetic susceptibility values are about 10×10^{-5} to 15×10^{-5} (SI units), which is fairly typical for Lake Michigan Lobe tills (Grimley, 2000).

Relatively thick silt deposits (about 5 m) above Glasford till record an unusual history and contain perhaps the most interesting features at this site. The distortion of thin silty clay layers within a primarily silty unit is the most unusual aspect of this deposit, stratigraphically known in Illinois

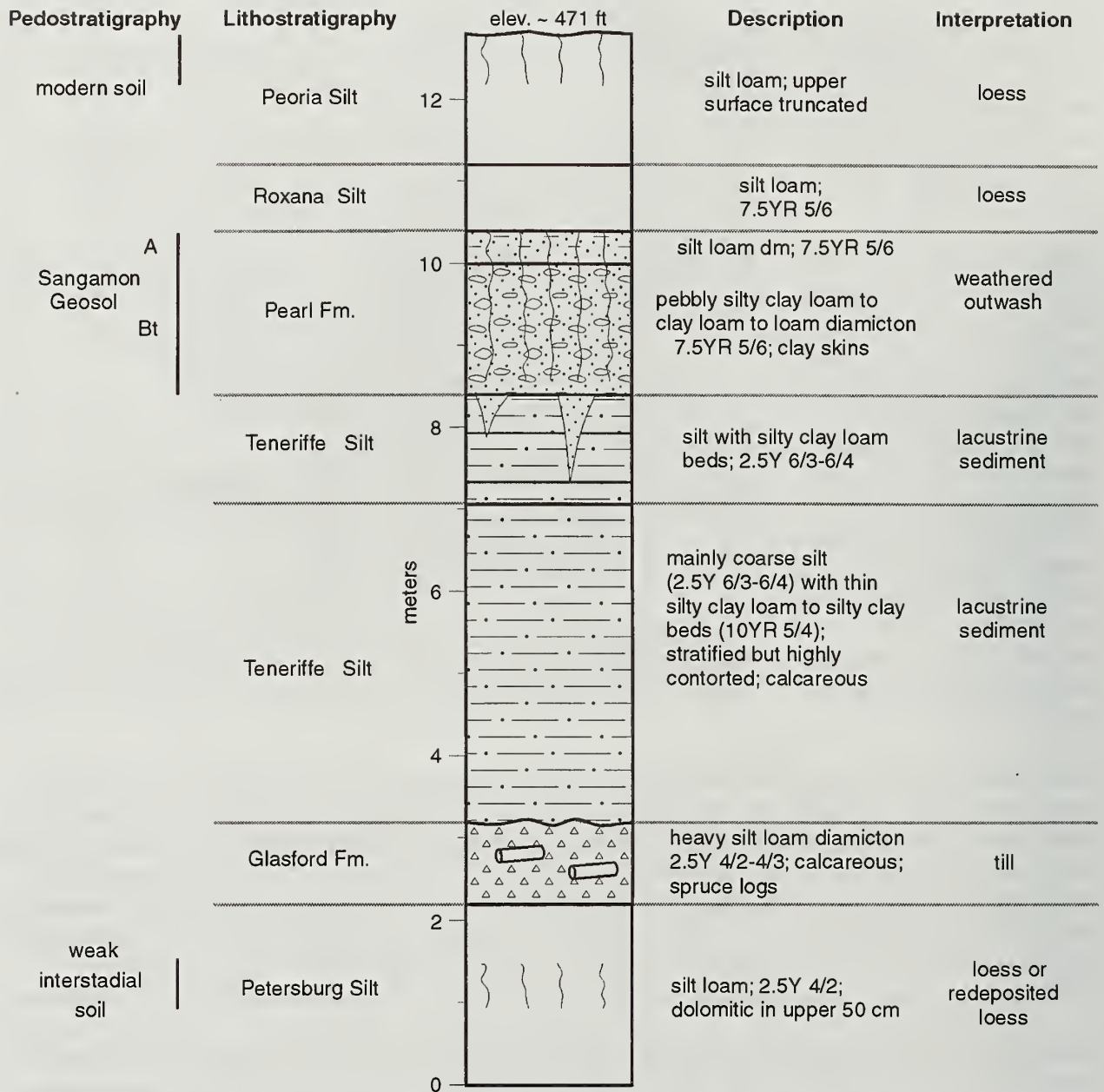


Figure 2-6. Stratigraphic column summarizing findings at Kane Quarry. Described in August 2000 by David A. Grimley and Andrew J. Stumpf. The section base is the approximate level of the limestone bedrock surface.

as the Teneriffe Silt (Willman and Frye, 1970). The origin of these features may be due to some combination of deformation and liquefaction processes. Some contacts of the thinner silty clay layers appear to have a surface similar to a flame structure (mud wisp), which was later deformed, perhaps from dewatering. Large paleoslump structures showing evidence of movement toward the valley of Macoupin Creek were also observed within this lacustrine silt. Much of the Teneriffe Silt at this site has a low clay content, seems to be rich in coarse silt, and is highly calcareous. Coarse silt deposits, such as these with little cohesion from clay particles, are susceptible to liquefaction. Low magnetic susceptibility values of 10×10^{-5} to 20×10^{-5} (SI units) are similar to those of the underlying diamicton and suggest derivation by fluvial sorting of deposits from

the glacial ice rather than having a large eolian input, which would generally result in higher susceptibility values.

Two sub-vertical fractures, up to several inches wide, were infilled with sand in the upper portion of Teneriffe Silt (fig. 2-6). These sand-filled fractures may have formed in a manner similar to that described by Huddard and Bennett (2000) for smaller sand-filled desiccation cracks. Vertical cracks may have formed by repetitive wetting and drying or freeze-thaw periglacial processes. Evidence at this site suggests that the cracks were filled in with proglacial outwash, which occurs above and lateral to the sand-filled fractures.

The Sangamon Geosol, a paleosol representing the last interglacial interval, occurs in a silty clay loam to clay loam diamicton up to 2 m thick. The origin of the diamicton is interpreted to be a weathered outwash bioturbated with loess. In some areas, the sand and gravel thickens slightly so that original bedding is apparent. Thicker sand and gravel was noted to occur laterally near the top of one of the sand-filled fractures. Large magnetic susceptibility values in the Sangamon Geosol solum (50×10^{-5} to 75×10^{-5} [SI units]) are interpreted to be a result of bacterially mediated ferrimagnetic neof ormation during soil development.

The Sangamon Geosol is overlain by 2–3 m of Wisconsinan loess that has been leached of carbonates. The contact of the weathered outwash with the loess above is gradational, such that pebbles are sporadic through the lower portions of the Roxana Silt unit, likely due to bioturbation of the two depositional units. Delineation of the Peoria and Roxana Silts was impractical at this site without laboratory data because of inaccessibility and because both units are leached of carbonates and oxidized. Some of the upper Peoria Silt and the modern soil has been stripped by quarry excavations.

Points to ponder

- *What is the origin of the sand-filled fractures?*
- *By what mechanism did the lake form (proglacial, supraglacial, or other)?*

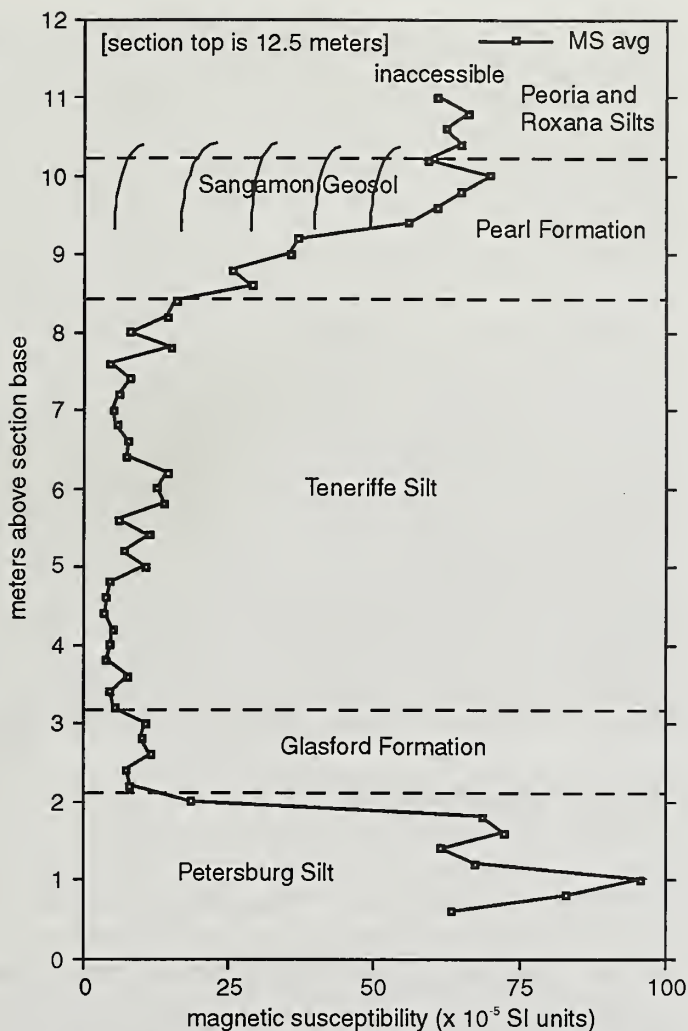


Figure 2-7. Magnetic susceptibility of Kane Quarry Section; values are an average of three readings measured at each depth.

Table 2.1: Oriented wood fragments in Glasford Formation diamicton.

Length of wood fragment (inches)	Orientation	Plunge/direction
14	N56°E	2°NE
3	N67°E	not measured
3	S70°E	8°E
5	N66°E	15°NE
2	N55°E	6°NE
4	N77°E	12°NE
4	S79°E	9°E
7	S60°E	10°E
2	S64°E	not measured
1	N77°E	5°NE
2	N66°E	not measured

Stop 3: Mason Hollow Section (Grimley, Phillips, and Follmer)

Grafton 7.5-minute Quadrangle, NE, SW, NE, Sec. 9, T6N, R12W, Jersey County, Illinois. Top elevation, ~497 ft; bedrock elevation, ~ 485 ft.

Overview The Mason Hollow Section (field site GFT-4f of Grimley, 1999a) is located about 0.5 mi north of Grafton and about 0.75 mi north of the confluence of the Illinois and Mississippi Rivers (fig. 2-8). This site, a 12-ft high creek bank, was exposed in part from the anthropogenic effect of constructing a culvert under Mason Hollow Road just upstream from the outcrop. The outcrop is tens of feet in length and exposes silty and cobbly alluvium, underlain by fossiliferous fine-grained sediment of the last glaciation (figs. 2-9 and 2-10). Bedrock occurs underneath this sequence at about creek level and also outcrops extensively in the uplands adjacent to this narrow valley.

Site Details Crudely laminated silt (Equality Formation), about 3 ft thick, at the base of this outcrop is calcareous and rich in fossil wood, seeds, needles, cones, and moss. This sediment, at an elevation of about 485–490 ft, is envisioned to be near where Mason Hollow Creek entered a slackwater lake of the Illinois and Mississippi Rivers (fig. 2-8). In this possibly deltaic setting, alternating fluvial, palustrine, and lacustrine environments may have occurred in response to variations in the level of the Illinois and Mississippi Rivers and lake level variations, stream avulsions, and sedimentation rate changes. Cross-bedding near the base of this unit, abundant spruce wood debris throughout, scour surfaces, and interspersed thin sand beds, particularly at the top and bottom of this unit, suggest an alluvial environment during some phases of deposition. This suggestion contrasts with the fine-grained nature of most of this unit and the occurrence of ostracodes, which support periods of shallow water deposition. The sediment probably was primarily derived from the Mason Hollow drainage basin. Woody debris and loessal deposits from the uplands undoubtedly were washed into this steep-walled valley. However, there also could have been some input from backwaters of the Mississippi and Illinois Rivers. Sieved samples contain violet seeds, dwarf club moss, *Selaginella selaginoides* (spike moss), spruce cones, spruce

needles, and sedge seeds, indicating a boreal forest environment (Richard G. Baker, personal communication, University of Iowa, 1997). Sieved samples also contain rare gastropods and ostracodes. Gastropods, identified by Eric A. Oches (University of South Florida), are small (<4 mm) and include *Amnicola* (aquatic) and *Discus cronkhitei* (terrestrial). Ostracodes have an affinity to *Cypricercus*, which is found in Illinois today in springs. This similarity suggests very shallow fresh water with some spring discharge likely existed here (B.B. Curry, personal communication, 2001).

Fossil spruce wood (*Picea*) embedded within this silt was dated $19,370 \pm 200$ ^{14}C yr B.P. (ISGS 3582), which is similar to ages reported from Bellefontaine Quarry (formerly known as Jamestown Quarry) in Missouri about 10 mi southeast of this section (Hajic et al., 1991; Grimley et al., 1998). Radiocarbon ages on wood preserved in river-flooded sinkhole fills at this quarry (also at about 490 ft elevation) indicate three flooding events at about 19,800, 18,600, and 16,000 ^{14}C yr B.P. These deposits have been correlated to other glacial flood clay beds that are interbedded within loess deposits in the St. Louis area and occur at elevations between 485 and 500 ft (Hajic et al., 1991; Grimley et al., 1998). Therefore, deposition at Mason Hollow likely occurred during a phase of maximum aggradation of the Mississippi and Illinois Rivers during the last glacial maximum, perhaps during the deposition of the lower two clay beds in the region. Because the modern normal pool elevation of the Mississippi River is about 419 ft in this area (Elsah 7.5-minute topographic map, unpublished), these deposits record a flood at least 70 ft above the present river level and about 45 ft higher than the Great Flood of 1993 (Chrastowski et al., 1994).

Cobbly, bouldery gravel, as much as 3.5 ft thick, sharply overlies the fine-grained Equality Formation (figs. 2-9 and 2-10). The angular and slabby character of the clasts indicates proximal deposition and records a drastic change in transportational energy. Deposition of these coarse alluvial gravels could have occurred during cold climate conditions of the late Wisconsinan, during which enhanced colluviation occurred along with some reworking by fluvial processes. One scenario might have been that a rockfall occurred slightly upstream and the angular cobbles were transported to this site during a storm event. Slope processes and river incision would have been accelerated immediately after slackwater lake levels dropped. It is also possible, however, that several thousand years elapsed before the alluvium was deposited. Dominantly limestone and chert lithologies indicate a local source area. Rare, small erratic pebbles may

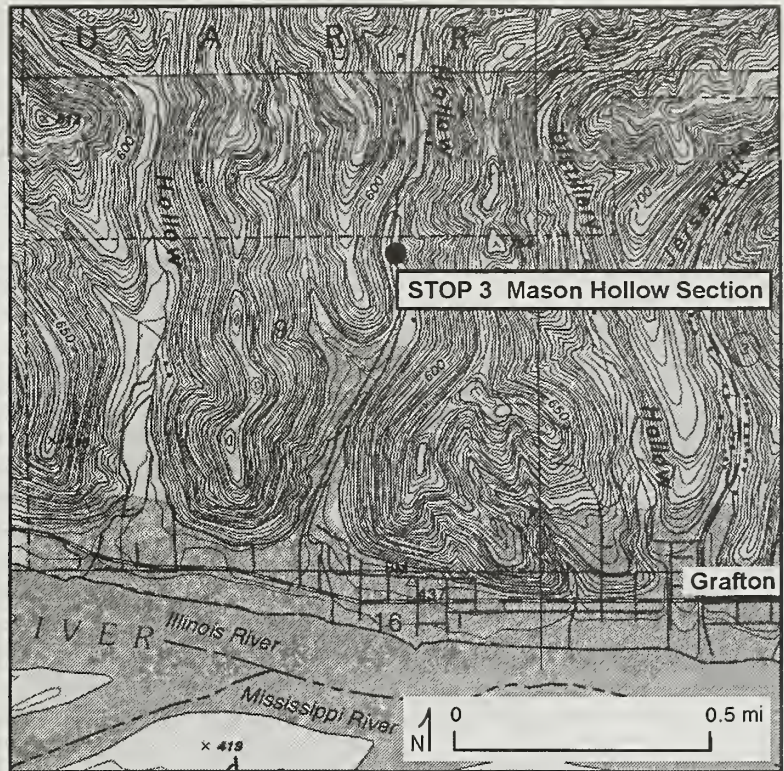


Figure 2-8. Location of Stop 3 (Mason Hollow Section) in a portion of the Grafton 7.5-minute Quadrangle. Maximum height of slackwater lakes during the peak of the last glaciation was about 485 ft. Areas up to 440 ft were flooded in 1993.

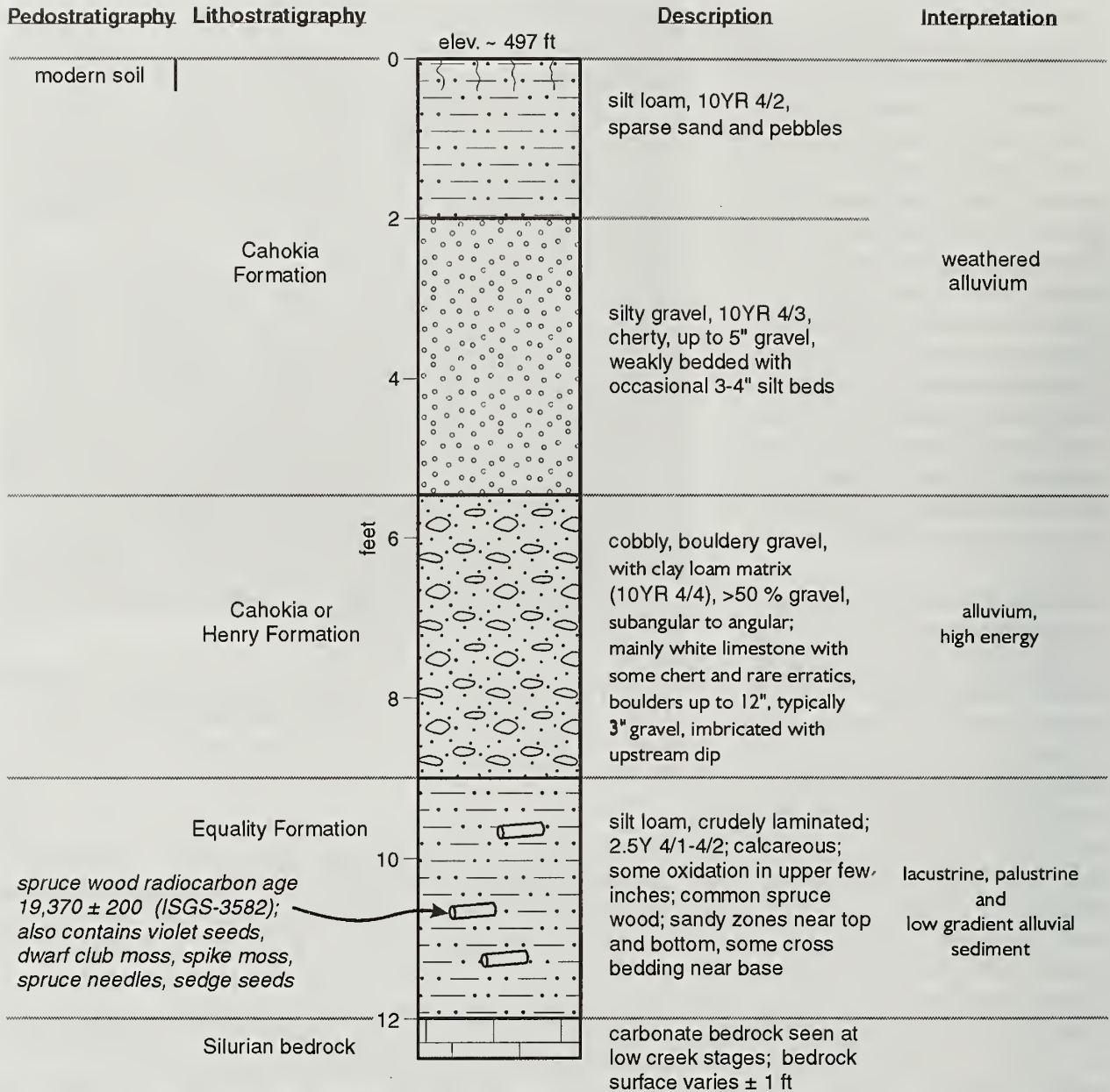


Figure 2-9. Stratigraphic column summarizing findings at the Mason Hollow Section. This exposure, about 30 ft wide on the east side of creek just downstream from a culvert, was described in February 1997 and also in August 2000 by David Grimley, Andrew Phillips, Leon Follmer, and Andy Stumpf.

have originated from erosion of till or glacial outwash deposited in the drainage basin during either the Illinoian or pre-Illinoian ages. However, because direct glacial deposits are not known in this drainage area (Grimley, 1999a), an alternative possibility is that erratics were ice-rafted to these elevations by peak glacial floods of the Illinois and Mississippi Rivers and later reworked into these alluvial deposits. This idea could be tested by searching for erratics at elevations above 500 ft. This unit could be correlated to either the Henry Formation or Cahokia Formation, depending on a Wisconsinan or Holocene age.



Figure 2-10. View of Mason Hollow Section showing cobbly limestone and chert gravel alluvium overlying crudely stratified silt.

Another 3.5 ft of crudely bedded silty gravel alluvium occurs above the coarse alluvium (figs. 2-9 and 2-10). This sediment is not as cobbly as below and does not contain any boulders. A lower content of limestone and higher content of chert are likely a result of postdepositional weathering. Minor silt beds within this unit may record calmer periods of overbank deposition. This unit is most likely Holocene in age and is correlated to a portion of the Cahokia Formation.

The uppermost 2 ft of silty alluvium is mainly redeposited loess with sparse reworked pebbles (figs. 2-9 and 2-10). It is leached and weathered but does not contain a well-developed modern soil. Thus, the age of this deposit is likely late Holocene or historical, perhaps representing sedimentation during deforestation of agricultural lands in the northern portion of the Mason Hollow drainage basin.

Flooding in the Grafton Area Severe flooding occurs periodically in the Grafton area. During the flood of 1993 (Chrzastowski et al. 1994), the confluence of the Illinois and Mississippi Rivers rose to an elevation of 442 ft, inundating much of downtown Grafton and leaving behind a thin layer of clay on the floodplain west of downtown. A new community of homes, available to residents of Grafton, has been constructed on uplands about 1 mi north of the town; however, many homes and businesses remain in the floodplain. Structures at low elevations on the western side of downtown Grafton near the mouth of Mason Hollow are especially vulnerable (fig. 2-8).

Points to ponder

- *What environment does the Equality Formation represent?*
- *What mechanism caused the extreme change in depositional energy between the silt and cobbly gravel?*

Stop 4: Piasa Creek Terrace (Grimley)

Elsah 7.5-minute Quadrangle, NW, NW, NE Sec. 26, T6N, R11W, Jersey County, Illinois. Top elevation, ~475 ft; bedrock, not reached at 366 ft.

Overview At Stop 4 (fig. 2-11), field trip participants can view the landscape and examine a 109-ft core (ELS-1) drilled into the Piasa Creek Terrace, on the grounds of Lockhaven Country Club. Along the lower Piasa and Mill Creek valleys, terraces occur at an elevation of about the 470–490 ft, but these elevations appear to decrease to 460 ft a few miles upstream. These terraces, capped by a few feet of loess, contain thick deposits of fine-grained lacustrine sediments (slack-water lake deposits). These sediments are interpreted to have been deposited by the backwaters of the Mississippi River that inundated these areas at the peak of the last glaciation. Sediments (fine sand to silty clay) are more than 109 ft thick at this site (fig. 2-12) near the confluence with the Mississippi Valley, but thin to less than 10 ft upstream a few miles. Based on their elevation, loess cover, and sediment record, these terraces are probably correlative to the Cuivre level of the St. Charles Terrace Group, noted by Hajic et al. (1991) in the St. Louis area. Mississippi River downcutting, which formed this terrace level, is estimated have occurred between about 17 ka and 15.5 ka; thus, sediments in these terraces are presumably this age or older (Hajic et al., 1991).

These lacustrine sediments are correlated to the Equality Formation and occur in much of the St. Louis area either in terraces or below post-glacial Cahokia alluvium at elevations below 490 ft (Goodfield, 1965; Hajic et al., 1991). Additionally, waterlain clay beds commonly interfinger with loess deposits in the region at elevations between 485 and 505 ft and have been radiocarbon dated between 20,000 and 16,000 ¹⁴C yr B.P. (Hajic et al., 1991; Grimley et al., 1998).

Core ELS-1 In core ELS-1 (fig. 2-12), drilled on undisturbed ground in the heart of the Piasa Creek Terrace (fig. 2-11), about 60 ft of yellow-brown to gray silt, clay, and fine sand (upper Equality Formation), capped by 5 ft of weathered loess (Peoria Silt), was found to overlie 44 ft of red-brown to pink to grey silty clay (lower Equality Formation). The lower unit contains scattered gastropods (snails) and is particularly fossiliferous near the core bottom (105–108 ft). The accelerator mass spectrometer (AMS) radiocarbon ages of 29,600 ± 700 [A-0011; shells], 42,000 ± 3,100 [A-0010; shells], and 43,772 ± 1590 [A-0022; δ¹³C –26.6; seeds] were determined at depths of 66, 105, and 107 ft, respectively. These ages essentially bracket deposition of the lower Equality Formation between 45,000 and 29,000 ¹⁴C yr B.P. This time interval is similar to that for deposition of a pinkish brown loess in the St. Louis area (Roxana Silt), which occurred between about 55,000 and 27,000 ¹⁴C yr B.P. (McKay, 1979b; Hansel and Johnson, 1996). This synchronicity and the similarity in color suggest that the lower Equality Formation includes a significant amount of redeposited Roxana Silt. Further evidence is that lower Equality sediments have a greater proportion of kaolinite and/or chlorite in the clay fraction and a smaller diffraction intensity ratio than do upper Equality sediments (Table 2-2). These differences are analogous to compositional differences between the Roxana and Peoria Silts (Frye et al., 1962; Grimley et al., 1998).

Abundant fossils within the lower Equality Formation at the depth of 105–108 ft have revealed significant information concerning the climatic and environmental conditions of the area during the middle Wisconsinan. Gastropod varieties include several aquatic genera and species (*Gyraulus*, *Amnicola*, and *Valvata tricarinata*) that typically live in slow-moving water. Small (2.5-mm) bivalve shells were also present. Ostracodes, examined by B.B. Curry (ISGS), include abundant *Candona*

caudata and *Candona rawsoni* and uncommon *Limnocythere herricki*. This assemblage supports the sedimentological and gastropod evidence of slow-moving or standing water. This ostracode assemblage is also indicative of a climate that was as dry or drier than today, such as that in northwestern Iowa, the Dakotas, or the Canadian prairies (B.B. Curry, personal communication, 1999). Plant macrofossils, examined by R.G. Baker (University of Iowa), include common chenopods and amaranths (these prairie taxa are herbs that grow on floodplains) and one poorly preserved spruce needle. These taxa include prairie taxa, some of which occur in the northern Great Plains today. Ostracode and macrofossil assemblages for this zone are similar to those found in pollen zone 5 of Raymond Basin, about 40 miles to the northeast in Montgomery County, Illinois (Curry and Baker, 2000). The overall environmental interpretation for this basal zone of the lower Equality Formation is a slightly cooler and drier climate than at present. An aggrading Mississippi River caused a lake to form in Piasa Creek valley into which loess and other sediment that eroded from the uplands was periodically washed and deposited.

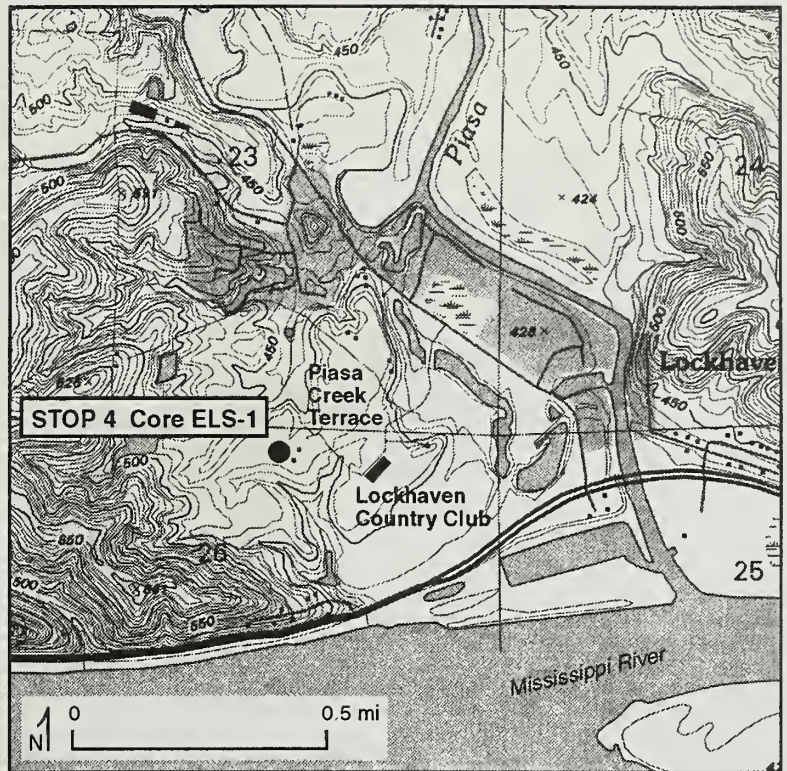


Figure 2-11. Piasa Terrace location. Elevations up to about 440 ft were flooded in 1993.

The overall environmental interpretation for this basal zone of the lower Equality Formation is a slightly cooler and drier climate than at present. An aggrading Mississippi River caused a lake to form in Piasa Creek valley into which loess and other sediment that eroded from the uplands was periodically washed and deposited.

Note on the Great Flood of 1993 The “Great Flood” of the Mississippi River during 1993 greatly affected this region (Chrzastowski et al., 1994). In the area near Piasa Terrace, floods reached an elevation of about 442 ft (more than 30 ft above normal levels), thus surrounding the Lockhaven Country Club (fig. 2-11). According to Steve Velsor, of the Lockhaven Country Club and resident on the club grounds, he and his family had to climb over the bluffs in order to get to a vehicle and a road that was passable along Route 3. Although the 480-ft terraces were not flooded themselves, most of the lower Piasa Creek floodplain and the roads alongside it were inundated.

Points to ponder

- What was the relative contribution of the Mississippi River versus tributary sources to the Equality Formation?
- What was a typical water depth of the lake?

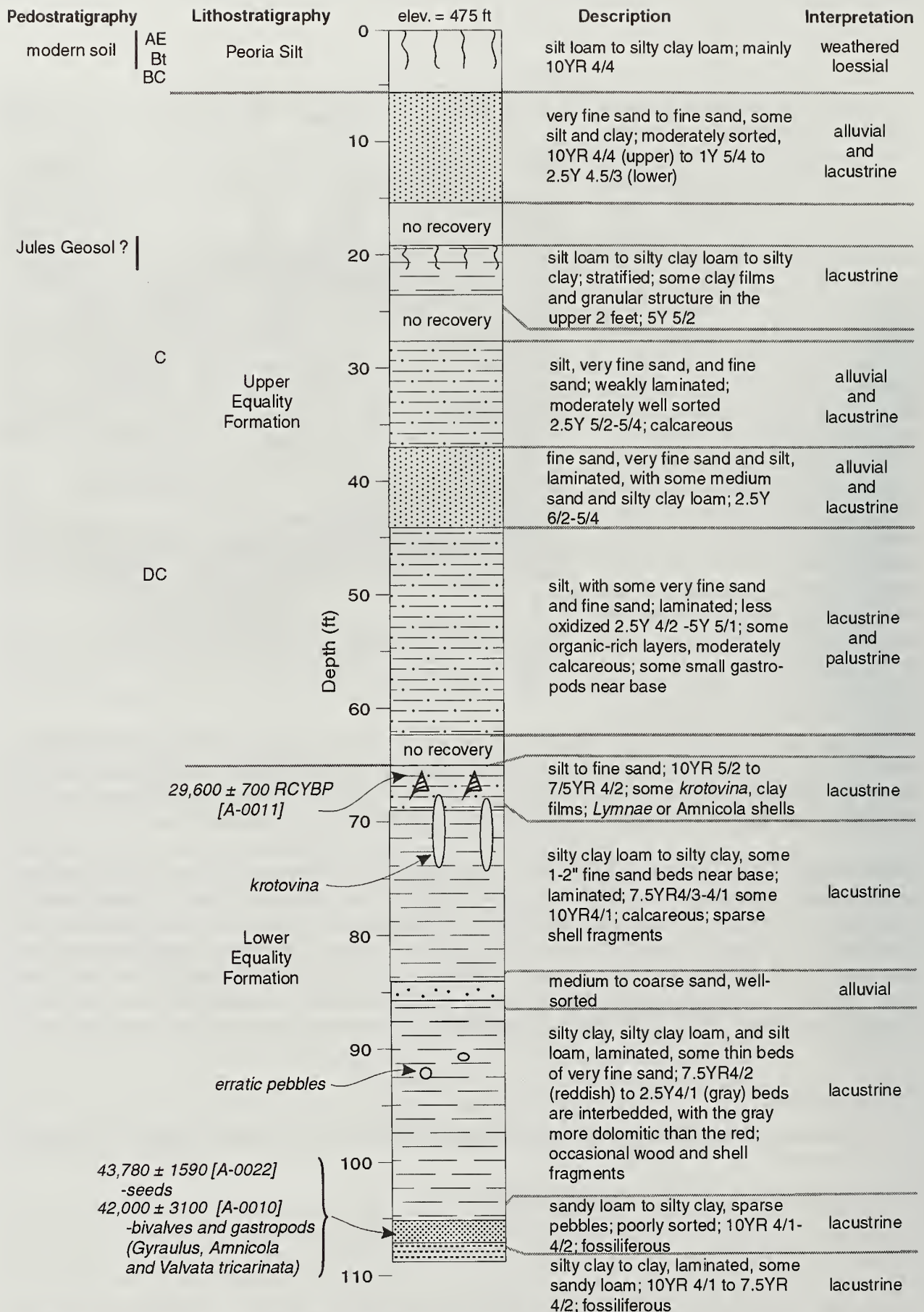


Figure 2-12. Stratigraphic column summarizing findings in the Piasa Terrace Core (ELS-1). This core was drilled by Meyer Drilling on the grounds of Lockhaven Country Club on the flat top of terrace in March 1998. Described by David Grimley and Christine Wiscombe.

Table 2-2: Clay mineralogy results from core ELS-1 (courtesy of H.D. Glass).

Sample depth (approx. ft)	Formation	Clay mineralogy ¹			D.I. ratio ²
		Exp.	Illite	K + C	
36	Upper Equality	78	14	7	1.32
66	Lower Equality	55	28	16	1.16
71	Lower Equality	59	25	15	1.10
90	Lower Equality	61	22	16	0.91
105	Lower Equality	46	31	23	0.89

¹Estimated percentage of clay minerals of total clay minerals in the <2- μ m fraction: expandables (Exp.), illite, and kaolinite plus chlorite (K + C).

²Diffraction intensity ratio.

Stop 5: Lohr Quarry (Grimley and Phillips)

Alton 7.5-minute Quadrangle SE, Sec. 5, T6N, R10W, Madison County, Illinois. Surface elevation, ~ 538 ft; bedrock, ~ 511 ft.

Overview Lohr Quarry (field site ALT 12f of Grimley, 1999b), located about 7 mi northwest of Alton near Little Piasa Creek (fig. 2-13), provides an excellent example of the typical surficial (Quaternary) deposits found in the Alton area. The exposures of overburden on the highwalls reveal about 11 ft of Wisconsinan loess, underlain by Illinoian glacial deposits and patchy pre-Illinoian deposits (fig. 2-14). Striations are often visible on the bedrock surface.

Site Details Two Wisconsinan loesses are present, both of which were deposited by periodic dust storms that deflated sediment from the Mississippi and Illinois River valleys. Peoria Silt, the upper yellow-brown loess, contains the modern soil in its upper portion. Roxana Silt, the lower loess, is pinkish brown, primarily because it contains more reddish sediment that was ultimately derived from the Lake Superior region (Grimley, 2000).

An interglacial soil (Sangamon Geosol) separates Wisconsinan loess deposits from Illinoian till. This paleosol formed during a period of warm interglacial conditions, similar to those of today (Curry and Baker, 2000). Along this outcrop, the Sangamon Geosol is reddish brown with gray mottles, indicating moderate drainage conditions during the Sangamonian. The paleosol also has well developed soil structure, particularly in its Bt horizon. The upper solum was developed into a thin deposit of late Illinoian loess (Teneriffe Silt).

Illinoian glacial materials include subglacial and supraglacial deposits, sands in glaciofluvial channels and beds, and colluvium. Interbedded sand and silt deposits, either supraglacial or proglacial, are as much as several feet thick in the northwestern corner of the highwall and overlie dense pebbly loam diamicton, interpreted as subglacial till. Grain size data (<2 mm) from two samples of subglacial till average 35% sand, 41% silt, and 24% clay (Table 2-3). Clay mineral data (<2 μ m) average 28% expandables, 57% illite, and 15% kaolinite plus chlorite. These data are similar to those for Illinoian till in the region, such as the Fort Russell Member of the Glasford

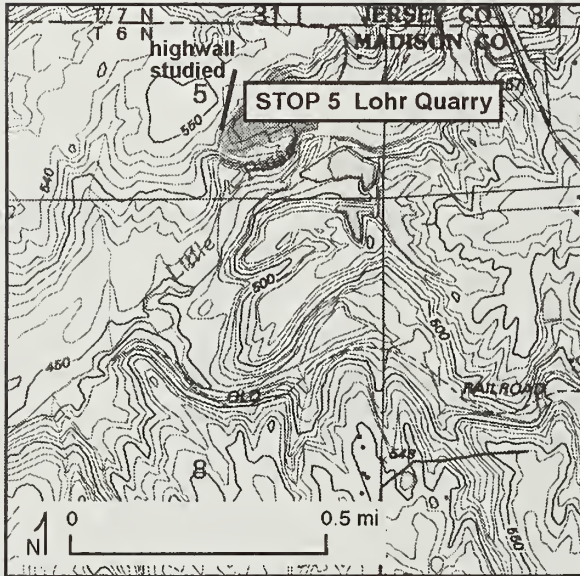


Figure 2-13. Location of Lohr Quarry in a portion of the Alton 7.5-minute Quadrangle.

Formation at the Paddock Creek Section about 15 mi to the east-southeast (Table 2-3; McKay, 1979b). Some sandy channel fills are also found within the subglacial till. One extensive sand layer (about 1–4 ft in thickness) was traced for a distance of more than 200 ft within the diamicton unit along the west highwall of the quarry in 1999 and 2000. Over most of the quarry exposure, the Illinoian till rests directly on fractured limestone or thin (eroded) bedrock residuum. Recent excavations (November 2000) have revealed many fractures in the limestone bedrock filled with Glasford till to a depth of 2 ft or more. Commonly these fills have caused shearing of red clay residuum on the sides of the fractures. The fills are interpreted to have been injected into the fractures by the force of overlying glacial ice.

Although pre-Illinoian till was not present at the measured section (fig. 2-14), an older brown silty clay loam diamicton is preserved in the north wall of the quarry, underneath the Illinoian till in a paleodepression on the bedrock surface. This oxidized and calcareous diamicton, interpreted as glacial till, is only about 5 ft thick. However, since the Glasford Formation is thinner over this area, the depth from Sangamon Geosol surface to bedrock is approximately 17 ft in most of the quarry. Except for the effects of oxidation, little evidence of an interglacial soil (Yarmouth Geosol) is present between the pre-Illinoian and Illinoian tills. However, we infer that considerable erosion occurred as a result of the subsequent advance of Illinoian ice because the color, texture, and mineralogy of the till compare well with regional observations of pre-Illinoian tills where a paleosol is present in the top of the pre-Illinoian diamicton (McKay, 1979b). Data on average grain size (<2 mm) of 22% sand, 45% silt, and 33% clay (Table 2-3) indicate less sand and more clay in this till unit than in the Illinoian till above, a noticeable difference in the field. Average clay mineralogy results (<2 μm) of 36% expandables, 45% illite, and 19% kaolinite plus chlorite indicate that this till contains more expandables and kaolinite plus chlorite with a lesser proportion of illite than the overlying till. These data support a correlation to pre-Illinoian (Omphghent member of the Banner Formation) till in the region, the type section of which is the Paddock Creek Section about 15 mi to the east-southeast (Table 2-3; McKay, 1979b).

Mississippian limestone bedrock underlies either Illinoian or pre-Illinoian till at the quarry. In places, the limestone surface is extensively striated and contains hairpin erosion marks (fig. 2-15), which are excellent indicators of ice direction. Striation orientations, measured in a western portion of the quarry on the bedrock surface below D horizon Illinoian till, appear to group in two directions, with one set indicating ice flow from about N55°E (55°, 54°, 55°) and the other from about N40°E (42°, 40°, 41°, 39°, 36°, 37°). Based on cross-cutting relationships of the scratches, the N55°E striae are the older of the two sets. Whether both sets of striations are from Illinoian glacial advances or whether one set is Illinoian and the other pre-Illinoian is not certain. However, both sets are likely Illinoian because they occur only in areas where nearby Illinoian till rests on bedrock. Hairpin erosion marks, elongate grooves normally formed around a small obstacle (Bennett and Glasser, 1996, p. 116), are typically about 1–2 m in length at the quarry and are associated with parallel striations and grooves within and surrounding them (fig. 2-15). The hairpin erosion marks

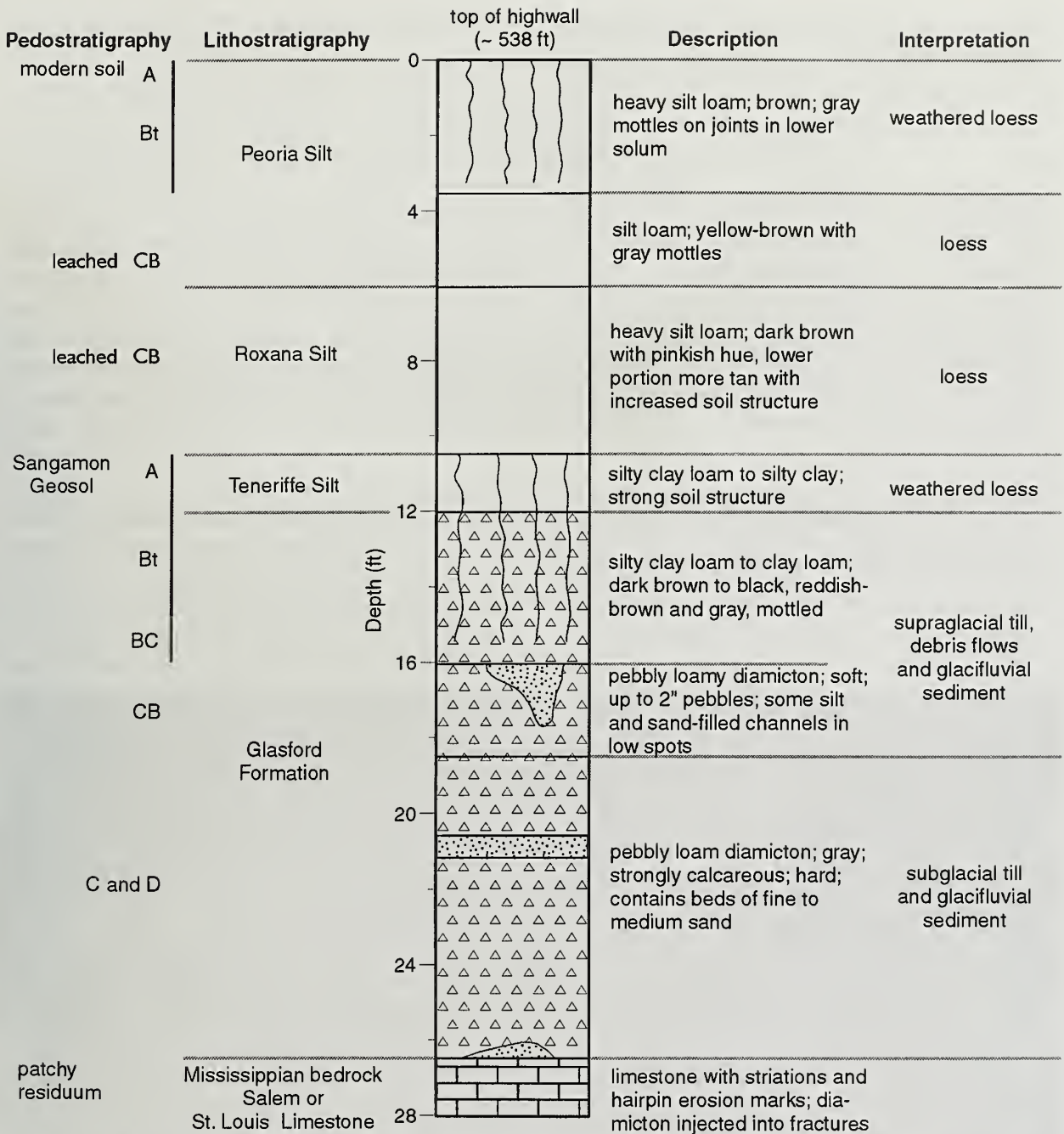


Figure 2-14. Stratigraphic column summarizing findings at Lohr Quarry. The northwest end of the highwall was described on July 8, 1997 (exposure) by David A. Grimley and E. Donald McKay. The majority of striations and hairpin erosion marks were observed and measured in June 1999.

are interpreted to have formed by glacial abrasion around nodules of chert which form the obstacle about which the marks bend. Alternatively, they may have formed partially by erosion from water or a water-sediment slurry. The hairpin erosion marks are important complements to the striations because the tails of these erosional marks are unidirectional ice flow indicators, pointing to the southwest at this site.

Table 2-3: Grain size and compositional data for tills at Lohr Quarry and comparison with Paddock Creek (from McKay, 1979b).

Site	Geologic unit	Grain size data ¹				MS ² (x 10 ⁻⁵ SI units)	Clay mineralogy ³		
		Gravel	Sand	Silt	Clay		Exp.	Illite	K + C
Lohr Quarry	Glasford Fm.	5.9	35.3	41.6	23.1		32	58	10
Lohr Quarry	Glasford Fm.	6.2	33.9	41.1	24.9	13	23	56	20
Lohr Quarry	Omphgent	3.3	22.1	45.4	32.6	14	36	45	19
Paddock Creek	Fort Russell	7.1	37.0	44.0	19.0	18	32	54	14
Paddock Creek	Omphgent	2.7	24.1	46.8	29.2	12–48	40	44	15

¹Gravel is expressed as the weight percent of bulk sample; sand (63 mm), silt (4–63 mm), and clay (<2 μm) are weight percent in the <2-mm fraction

²Magnetic susceptibility.

³Estimated percentages of minerals in the clay mineral fraction; peak intensities were measured by x-ray. Diffraction after glycolation; peak intensity factors of three times for illite and two times for kaolinite plus chlorite (K+C) were applied. Exp., expandable clay minerals, 17 Å peak; illite, 10 Å peak; K + C, 7 Å peak. Clay mineral measurements are courtesy of Herb Glass, Illinois State Geological Survey.



Figure 2-15. Hairpin erosion marks in the limestone at Lohr Quarry. Ice advanced from the right to the left (generally from the northeast direction).

Other striation orientations measured were about N20°E, N60°E, and N80°E. These directions could be related to the ice advance that deposited the pre-Illinoian Banner Formation because this till was present near where these striations were found. However, these striations are more weathered, are not as prominent as the others noted, are not associated with hairpin erosion marks, and are not grouped in one direction; thus, their reliability is more questionable.

Groundwater Issues The Quaternary deposits on uplands in the Alton area provide the framework for the development of low-yield water wells in the region. Well water for rural upland farms is commonly drawn from loose, sandy deposits in the upper portion of the Glasford Formation (supraglacial and proglacial facies) where water collects below the permeable loess and above the more dense and impermeable clayey basal till. Yields from these wells are relatively small and suitable only for household water supplies. Lower portions of the Fort Russell till are uniform in texture and are quite impervious to groundwater flow; thus, this unit is commonly drilled into for an additional 10 to 15 ft to provide reservoirs for groundwater entering the wells from more permeable units above.

Groundwater in the uplands is also commonly drawn from fractured limestone bedrock. Unfortunately, the limestone bedrock is generally cavernous, and these bedrock aquifers are susceptible to contamination through conduit flow (Panno et al., 1997). Henry Formation sand and gravel and Cahokia Formation sand in the Mississippi River floodplain constitute the most significant Quaternary aquifer in the Mississippi Valley bottomlands of the St. Louis Metro East area. Water yields from this aquifer are large; however, the potential for contamination is great because of the relatively thin covering of silt and clay (typically 0–40 ft).

Points to ponder

- *By what process did the till fill into these fractures?*
- *What is the origin of the sand layers within and above diamicton of the Glasford Formation (supraglacial or proglacial)?*

SITE DESCRIPTIONS: DAY 2 (ALTON TO BELLEVILLE)

Stop 6: Dunn Road Section (Grimley, Follmer, and Wang)

Columbia Bottom 7.5-minute Quadrangle, St. Louis County, Missouri and Illinois.

Overview The borrow pit, first studied in November 2000, is located in Missouri about 1,000 ft north of Interstate 270 near the Riverside Drive exit (fig. 2-16). This site is very close to the former exposure of the Chain-of-Rocks Section, which revealed similar geologic units during construction of I-270 in the early 1960s (Goodfield, 1965). Only 1,500 ft west of the Mississippi River, this borrow pit has been excavated into a hillside on the north side of Dunn Road. The soft Quaternary sediments at the Dunn Road Section, a succession of fluvial, lacustrine, glacial, and eolian deposits (figs. 2-17 and 2-18), are used for fill in area roadwork. The occurrence of Illinoian till verifies the crossing of glacial ice into Missouri during the Illinoian Stage, as was noted by previous researchers such as Goodfield (1965) and Robertson (1938). Fluvial deposits, older and younger than the till, are likely from ancestral high levels of the Mississippi River.

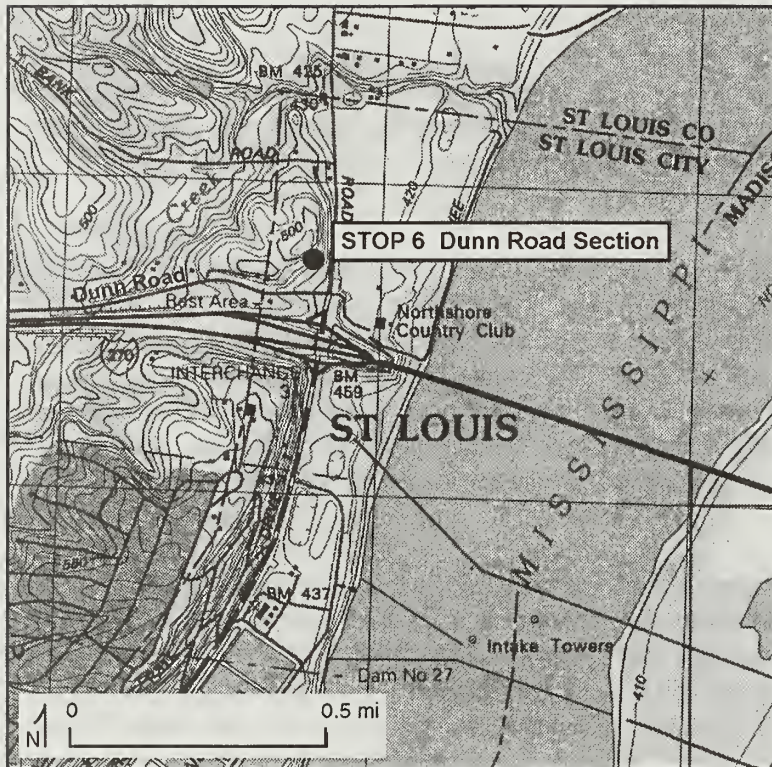


Figure 2-16. Location of Stop 6 (Dunn Road Section) in a portion of the Columbia Bottom 7.5-minute Quadrangle (Illinois-Missouri).

Site Details The oldest unlithified deposit at this locality is a highly weathered siliceous sand and gravel known as the Grover Gravel (Willman and Frye, 1970). The Grover Gravel, a nonglacial fluvial deposit emplaced before deep valley entrenchment began, is considered to be of Pliocene or early Pleistocene Stage. Although the type section of the Grover Gravel in western St. Louis County exposes 40 ft of sand and gravel (Willman and Frye, 1970), only about 7 ft occurs at this locality. The sand and gravel is highly weathered and becomes more clayey and reddish toward its top. At other locations in the region, the Grover contains clasts of Baraboo Quartzite (Willman and Frye, 1970), as well as jasper, indicating a Lake Superior Province source area.

Overlying the Grover Gravel is 1.5 ft of highly altered clay loam to clay. This unit has enough silt to indicate that it may include loessal additions admixed with sand that was bioturbated from below. The clay probably formed as a result of intense and long-term weathering of a pre-Illinoian loess, such as the Crowley's Ridge Silt (Porter and Bishop, 1990) and perhaps older loessal units as well. The strongly developed soil, containing an intensely developed Btt horizon, excessive amounts of fine clay, and a 4YR color, is in the Ultisol class and is pedostratigraphically the Yarmouth Geosol. In eastern portions of the borrow pit, this reddish clay is overlain by as much as 1.5 ft of a noncalcareous, brown silty clay loam with orange iron concretions. This unit appears to be an accretionary A horizon of the Yarmouth Geosol, but thins considerably to the west (uphill in both modern and paleotopography); it is interpreted as a depressional deposit.

As much as 11 ft of calcareous diamicton (Glasford Formation) sharply overlies the Yarmouth Geosol and associated deposits at the measured exposure. This unit, interpreted as till, thins to about 5 ft downslope to the east (fig. 2-17). Much shearing of the basal units is evident. The texture of this till is variable but is typically a clay loam diamicton. Large bodies of gravel (Grover Gravel?) and red clay (residuum or Yarmouth Geosol) occur within this till. These materials likely were incorporated into the base of the glacial ice locally as it eroded into the hillside after crossing the broad Mississippi River valley from the east. The incorporation of residual soil into glacial ice probably caused the more clayey nature of this till compared with that on the eastern side of the Mississippi Valley. Numerous erratics indicate a glacial origin for the unit. Regional indicators of ice direction (striations near Alton; e.g., Lohr Quarry, Stop 5) suggest ice flow from the northeast to east-northeast at this site (fig. 2-15). Goodfield (1965) also noted the presence of Illinoian till near the bluffs very close to this area at the Chain-of-Rocks Section as well as a few miles to the north and south.

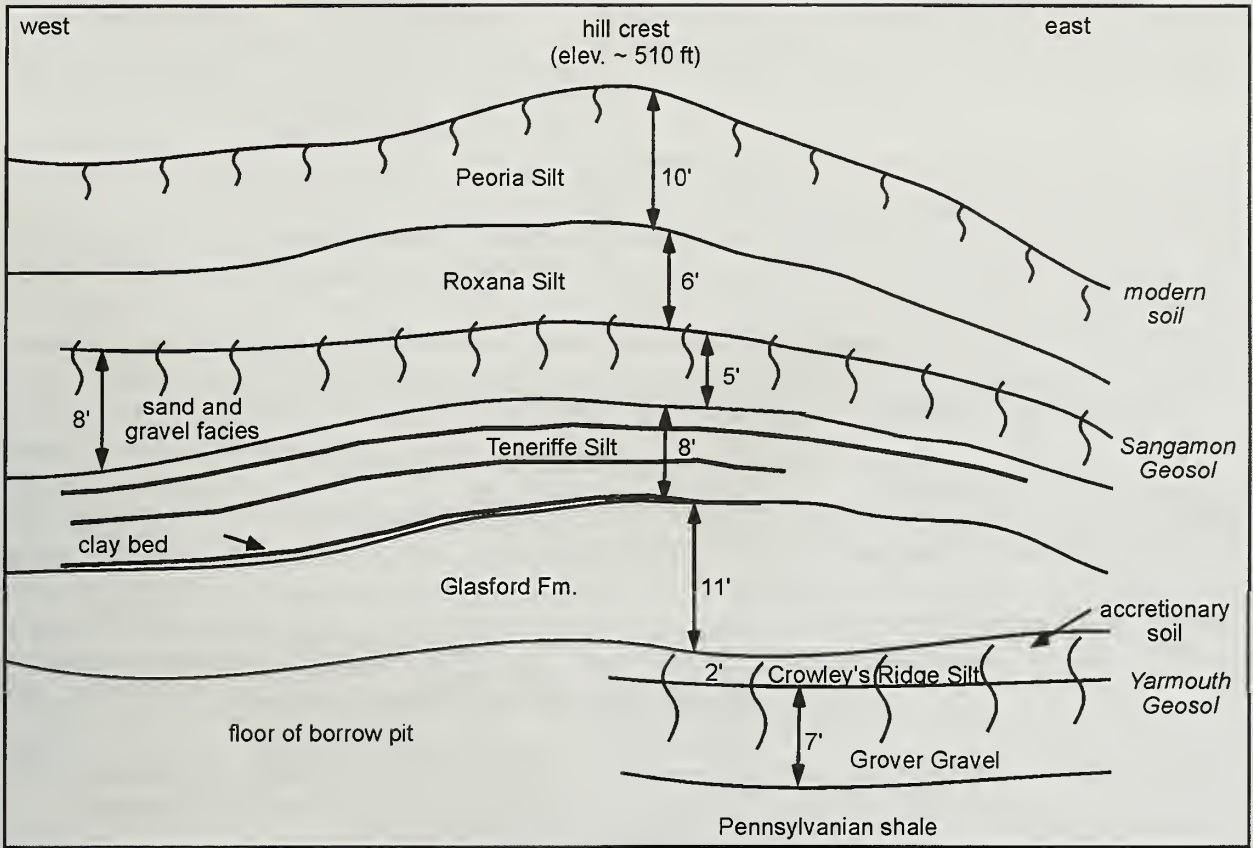


Figure 2-17. Sketch of Dunn Road Section on November 3, 2000.

Illinoian till is overlain by a thick succession of lacustrine and fluvial deposits (figs. 2-17 and 2-18). A 1-inch thick bed of calcareous silty clay just above the till is interpreted to be overbank sediment derived from a large-scale flood of the Mississippi and Missouri Rivers. This flood was perhaps the result of damming of these rivers by Illinoian ice. An additional 6 ft of finely laminated, strongly calcareous coarse silt (Teneriffe Silt) may have been deposited in an alluvial/lacustrine environment during this blockage. This silt contains some faint cross-bedding and contains another thinner clay bed in its middle portion and a 0.75-inch silty clay bed in its upper portion. Above, this succession coarsens upward. Silt and very fine sand, some of which may be eolian, quickly grade into weathered medium sand with a stone line above it containing up to 3-inch gravel clasts. This sand, interpreted as outwash, is similar to the Pearl Formation in other areas but is included in the Teneriffe Silt because of stratigraphic nomenclature rules (Willman and Frye, 1970). To the west of the described section, the weathered sand and stone line thicken to as much as 8 ft of bedded sand and gravel, with the lower surface dropping in elevation. Stratigraphic relationships at the exposure, including clear correlation of the clay bed layers, indicate that the stone line to the east may be an erosional remnant of the thicker sand and gravel to the west. Alternatively, the sand and gravel may have been originally thicker in the western portion of the pit, and the stone line could be in part pedogenic (Johnson and Balek, 1991). The coarsening-upward sequence of sand and gravel may be explained by general aggradation of the Mississippi River, perhaps during ice readvancement to just north of this area, which caused deposition of outwash. As a result of river aggradation during this deposition or perhaps during a torrent, the river may have topped glacial ice barriers in the valley and then gradually incised into the valley. Because of the paucity of Illinoian deposits in the Mississippi

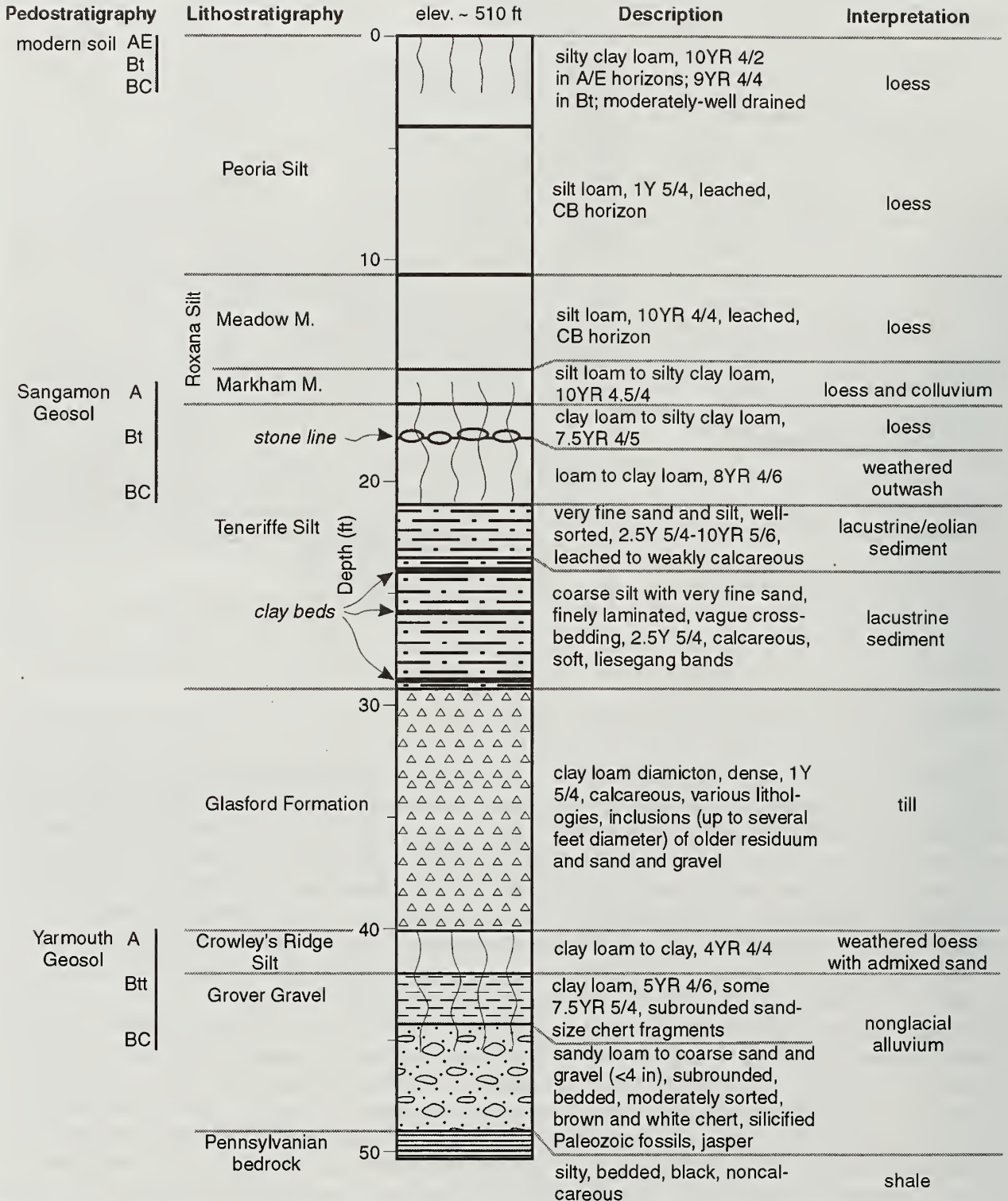


Figure 2-18. Stratigraphic column summarizing findings at the Dunn Road Section. This site was described by David Grimley, Hong Wang, and Leon Follmer in November 2000. The base of section is about 12 ft above intersection of Dunn Road and Riverview Drive.

Valley and its large tributaries, the level of the Mississippi River during Sangamonian time was likely much lower than it is today. Deposits above the fluvial deposits are loesses and soils typical for uplands in the St. Louis region.

The upper solum of the Sangamon Geosol is developed into 2–3 ft of loessal silt (Teneriffe Silt and Roxana Silt), which has since been altered to silty clay loam (fig. 2-18). Lower horizons of the Sangamon Geosol are developed in sandy outwash (mentioned above). The Sangamon Geosol exhibits its typical physical properties, which are similar to those at other sites on this field trip. The A horizon of the Sangamon Geosol has a cumulic character, having been developed as an early portion of the Roxana Silt was being deposited. This thin unit, known as the Markham Member of the Roxana Silt, and the polygenetic paleosol formed in it, can be philosophically distinguished as the Chapin Geosol (Willman and Frye, 1970), which is often wedded to, and inseparable from, the Sangamon Geosol.

The uppermost 15 ft of the Dunn Road Section is composed of Wisconsinan loess in various stages of alteration (fig. 2-18). Above the 1.5 ft of Markham Silt, 5 ft of Meadow Member of Roxana Silt occurs. This silt is brown to faintly pinkish brown and is leached of carbonates. The Peoria Silt, a more yellow-brown loess of late Wisconsinan Stage, is 10 ft thick, the uppermost 4 ft of which includes the modern soil solum. The modern soil appears to be developed into original ground on the hill crest and is a typical Alfisol (forest soil) for the area.

Points to ponder

- *Do the clay beds and lacustrine silt record an ice-dammed Mississippi River?*
- *What depositional environment does the Illinoian outwash above the silt represent: an ice readvance, general aggradation, glacial torrent, or other?*
- *Was the Mississippi River in its current valley during deposition of the Grover Gravel?*

Stop 7: Keller Farm Section (Wang, Follmer, and Grimley)

Monks Mound 7.5-minute Quadrangle, 1,150 ft north of the southeast corner, Sec. 32, T4N, R8W, Madison County, Illinois. Top elevation, ~545 ft.

Overview The Keller Farm Section is located immediately east of the Mississippi River valley about 12 miles northeast of St. Louis, Missouri (fig. 2-19). The Keller Farm borrow pit, formerly utilized as fill for many roads in the St. Louis Metro East vicinity, exposes 14 m (46 ft) of Peoria Silt, a loess unit deposited during the late Wisconsinan glaciation. The underlying Roxana Silt is only barely exposed in a gully at the base of this large exposure. The thickness of Peoria loess here is close to the thickest documented in Illinois and is in strong contrast to the considerably thinner deposits found 10 mi to the west at the last stop on this field trip (Dunn Road Section), where Peoria Silt is only about 3 m thick. This strong contrast in thickness is a result of the predominantly westerly winds during the last glaciation.

Site Details At Keller Farm, an estimated 39 successive beds of loess and paleosols are exposed (fig. 2-20). Close examination shows that the layers represent alternating paleosol A and C horizons. The dark or redder (humic-iron staining) finer grained zones are A horizons, and the yellowish, carbonate-enriched, and coarser grained zones are C horizons, less altered loess deposits.

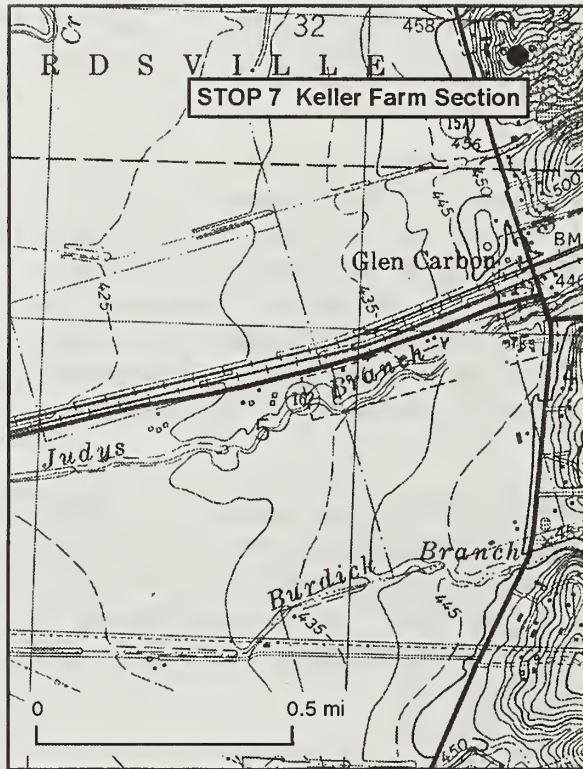


Figure 2-19. Location of the Keller Farm Section in a portion of the Monks Mound 7.5-minute Quadrangle. The elevation of the top of the section is about 545 ft.

the exposure, is around 25,000 ^{14}C yr B.P., which is consistent with previous estimates for the beginning of Peoria loess deposition in Illinois (McKay, 1979a). The ^{14}C ages from horizons 39, 28, and 12 (fig. 2-20) agree with the ages of paleosols described by McKay (1977), Follmer et al. (1979), and Frye et al. (1974), that is, the Ruby Lane (23,000 ^{14}C yr B.P.), Gardena (19,600 ^{14}C yr B.P.), and Jules (16,000 ^{14}C yr B.P.) soils, respectively. The age of 13,700 ^{14}C yr B.P. from horizon 8, about 1.2 m above the Jules (horizon 12), agrees with previous ^{14}C ages in the Illinois River valley (Grimley et al., 1998). The age of 11,400 ^{14}C yr B.P. from horizon 4 is comparable with the ages (11,000–12,000 ^{14}C yr B.P.) of a buried soil developed near the top of the Peoria loess in the Great Plains (Muhs et al., 1999) and the ages (11,700–12,000 ^{14}C yr B.P.) of the Two Creeks soil (Kaiser, 1994) outside the loess belt in the Midwest. This age-depth model produces a reasonable age estimate for this succession and yields resolutions of 140 and 70 yr per 10-cm sample interval for the upper and lower parts, respectively. This model suggests that the average loess deposition rate declined by a factor of 2 at about 17,000 ^{14}C yr B.P. (fig. 2-21).

We ranked buried A horizons using a numerical scale of soil development based on soil color (darkness and redness) and fabric (root traces and aggregate strength) (Follmer, 1998). The strongest expressed A horizon was assigned a soil development value of 2.0, and the weakest expressed horizon was assigned a value 0.2, which is a C horizon in a practical sense, because all horizons at this site have some pedogenic characteristics. Five classes (0.2, 0.5, 1.0, 1.5, and 2.0) were assigned to rank pedogenesis through the sequence.

Samples, collected every 10 cm vertically, were analyzed for magnetic susceptibility and organic carbon isotopes. Magnetic susceptibility is affected both by pedogenic (in situ formation; leaching)

A striking feature of this exposure is the quasi-periodic oscillations of A and C horizons or stronger A horizons and weaker A horizons. This site provides the best Peoria loess record in the Midwest and provides important evidence for millennial and shorter scale climate change studies of the last glaciation.

A total of 34 ages have been determined on soil organic matter (SOM) using conventional ^{14}C dating methods with large sample sizes (Wang et al., 2000). Separate radiocarbon age determinations were made on (1) total organic carbon (TOC), (2) pyrolysis-volatile, and (3) pyrolysis-residue fractions of SOM. Neither the TOC nor the pyrolysis-residue fraction showed a correlation with sample depth. Both fractions yielded ^{14}C ages that were unreasonably old. In contrast, fourteen ages determined from the pyrolysis-volatile fraction ages correlated with sample depth with a correlation coefficient of 0.93. When three relatively older ages are excluded, two best fit linear equations are obtained with correlation coefficients greater than 0.99 (fig. 2-21). This age-depth model suggests that the age of the bottom of the Peoria Silt, about 2 m beneath

processes (Maher and Thompson, 1995; Johnson and Willey, 2000) and by lithogenic (sorting, provenance) processes (Grimley et al., 1998) in loess-paleosol sequences. Soil organic matter accumulates from plant debris over many years, and their $\delta^{13}\text{C}_{\text{SOM}}$ reflects long-term annual average C_3/C_4 plant ratio (Wang and Follmer, 1998; Wang et al., 2000). The $\delta^{13}\text{C}_{\text{SOM}}$ and magnetic susceptibility values are plotted on the five classes of soil horizons (fig. 2-22).

Higher frequency variations in magnetic susceptibility appear to oscillate in phase with the $\delta^{13}\text{C}_{\text{SOM}}$ values, and higher values of both parameters typically correspond to stronger paleosol A horizons (fig. 7.4). Higher frequency variations in magnetic susceptibility, a result of either magnetite concentration during leaching or ferromagnetic mineral neof ormation, are superimposed on a broader lithologic pattern (fig. 2-22), which is likely a reflection of source area shifts (Grimley et al., 1998; Grimley, 2000). The $\delta^{13}\text{C}_{\text{SOM}}$ values, varying between -26.5% and -24% , indicate an 18% oscillation in the ratio of C_3/C_4 plants. Although $\delta^{13}\text{C}_{\text{SOM}}$ values can be interpreted to be the result of variations within C_3 plant regimes, other independent evidence suggests that the variations resulted from C_4 plant intrusions. For example, the $\delta^{13}\text{C}$ values of soil carbonate at this site indicate significant amounts of C_4 plants during growing seasons (Wang et al., 2000), and the pollen spectra of sites of the same age to the northeast also indicate the presence of C_4 plants (Gruger, 1972; King, 1979). One possible explanation for these correspondences is that sustained warm precipitation from the Gulf of Mexico air could have simultaneously favored paleosol development, in situ formation of ultrafine clay-size ferromagnetic minerals, and increased $\delta^{13}\text{C}_{\text{SOM}}$ values.



Figure 2-20. A view of the Peoria loess at the Keller Farm Section in 1999. Radiocarbon ages of some of the minor paleosols (dark bands) and depths are indicated on the photograph.

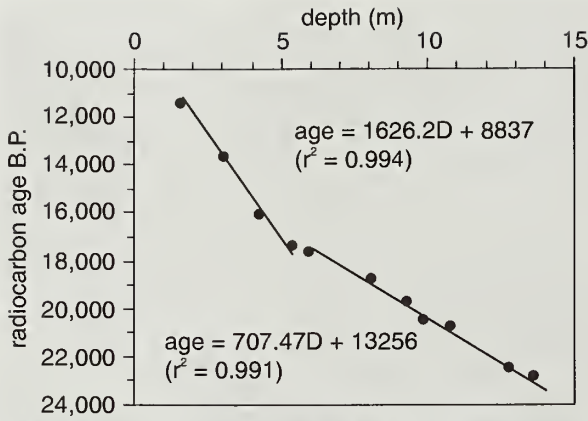


Figure 2-21. Carbon-14 age-depth models based on two best linear fits at the Keller Farm Section. Based on these models, the loess deposition rate slowed considerably after about 17,000 ¹⁴C yr B.P.

intensity, grain size sorting, and source variations in the Mississippi, Missouri, and Illinois River watersheds (McKay, 1977). Higher frequency variations in total carbonate content at the Keller Farm Section, primarily a leaching index, are thought to be superposed on a long-term trend of the source variations (McKay, 1977). Layers with smaller total soil carbonate (SC) content and smaller $\delta^{13}\text{C}_{\text{SC}}$ values (fig. 2-23) reflect warmer/wetter summers that are favorable for C_3 plant growth. Layers with greater total carbonate content and larger $\delta^{13}\text{C}_{\text{SC}}$ reflect colder, drier summers that would favor increased proportions of C_4 plants (fig. 2-23). Because these summer anomalies agree with regional records of historic El Niño events, we hypothesize that the oscillation of reconstructed summer/winter anomalies suggests paleo-El Niño-Southern Oscillation cycles (Wang et al., 2000).

Loess Erodibility Loess deposits are well known for their easy erodibility. The small clay content (<10% at Keller Farm) and large silt content in thick loess deposits provide for a largely cohesionless material that is easily mobilized by running water. At Keller Farm, in the last 3 years alone, erosional processes have enlarged a rill 10 ft deep into the dirt road to form a huge gully, which is visible at the base of the borrow pit and now exposes the upper few feet of the Roxana Silt.

We also analyzed $\delta^{13}\text{C}$ of carbonate in rhizoconcretions and the total soil carbonate content of the loess. The $\delta^{13}\text{C}$ values determined from these rhizoconcretions ($\delta^{13}\text{C}_{\text{SC}}$) are an indicator of the ratio of C_3/C_4 plants over the growing season, a proxy of warm-season climate (Wang and Follmer, 1998, Wang et al., 2000). Variations in total carbonate content also reflect mainly warm-season influences because rhizoconcretion formation and leaching of carbonate minerals, primarily dolomite (McKay, 1977), are mediated by soil moisture, which would be most active during the warm part of a year when the ground was not frozen. Total carbonate content can reflect changes in leaching

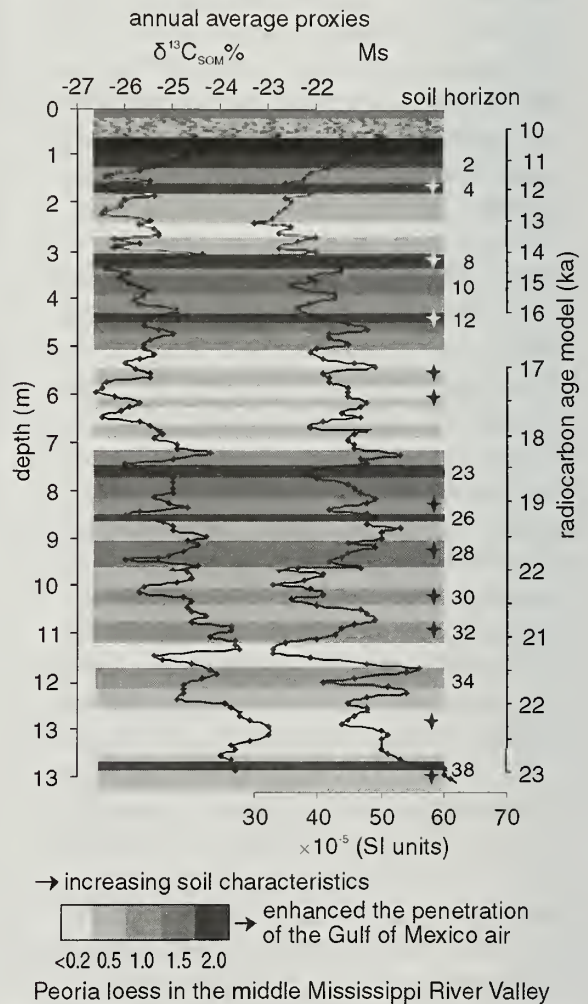


Figure 2-22. $\delta^{13}\text{C}_{\text{SOM}}$ and magnetic susceptibility are plotted on a background showing the five classes of soil horizons at the Keller Farm Section. The darker bands indicate stronger paleosol development, based on morphology and color.

Points to ponder

- To what degree are the cyclical patterns in the data from Keller Farm controlled by climatic versus other causes?
- To what extent were climatic cycles in phase with fluctuations of the Laurentide Ice Sheet in midwestern glacial lobes?

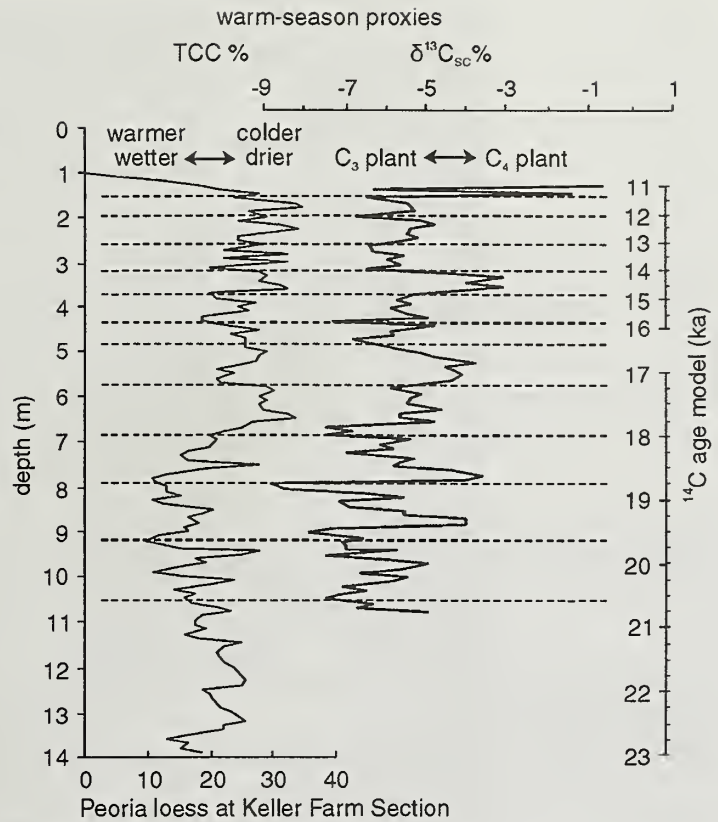


Figure 2-23. Total carbonate content (TCC) and $\delta^{13}\text{C}_{\text{sc}}$ plotted versus depth for the Keller Farm Section. Zones of lower TCC and lower $\delta^{13}\text{C}_{\text{sc}}$ are interpreted as representing warmer and wetter climates during growing seasons.

Stop 8: La Brot Borrow Pit (Phillips and Grimley)

Collinsville 7.5-minute Quadrangle, Brookhaven Road, NE, NW, NW Sec. 3, R8W, T2N, St. Clair County, Illinois.

Overview Sediments exposed at the La Brot borrow pit, near the town of Collinsville, include two Wisconsinan silt units and Illinoian diamicton (fig. 2-24). The Peoria Silt is here much thinner than at the Keller Farm site, but color zonations, gleyed horizons, and subtle redoximorphic features are preserved in the underlying Roxana Silt (figs. 2-25 and 2-26). Two separate pits enable us to examine lateral variations of the Sangamon Geosol, which is developed in diamicton and silt and contains a prominent stone concentration. Nearby, Pennsylvanian shales crop out in adjacent valleys at an elevation just below the base of the pit. This bedrock has been deeply incised west of the borrow pit in Canteen Creek valley (fig. 2-24), which is filled with up to 50 ft of Wisconsinan and possibly Illinoian lacustrine silts and alluvial silts, sands, and gravels and is capped by recent alluvial silts.

Safety note: *Mr. La Brot is concerned about sudden collapse of the pit wall, and you should be, too. Please remain attentive and approach the exposure cautiously.*

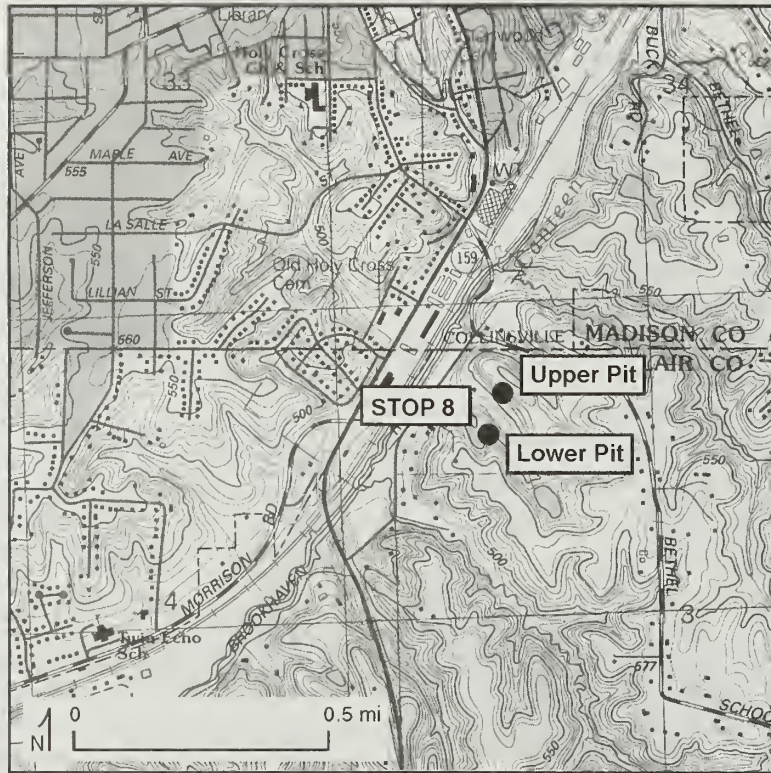


Figure 2-24. Location of the La Brot borrow pit in a portion of the Collinsville 7.5-minute Quadrangle. Topography was updated in 1986.

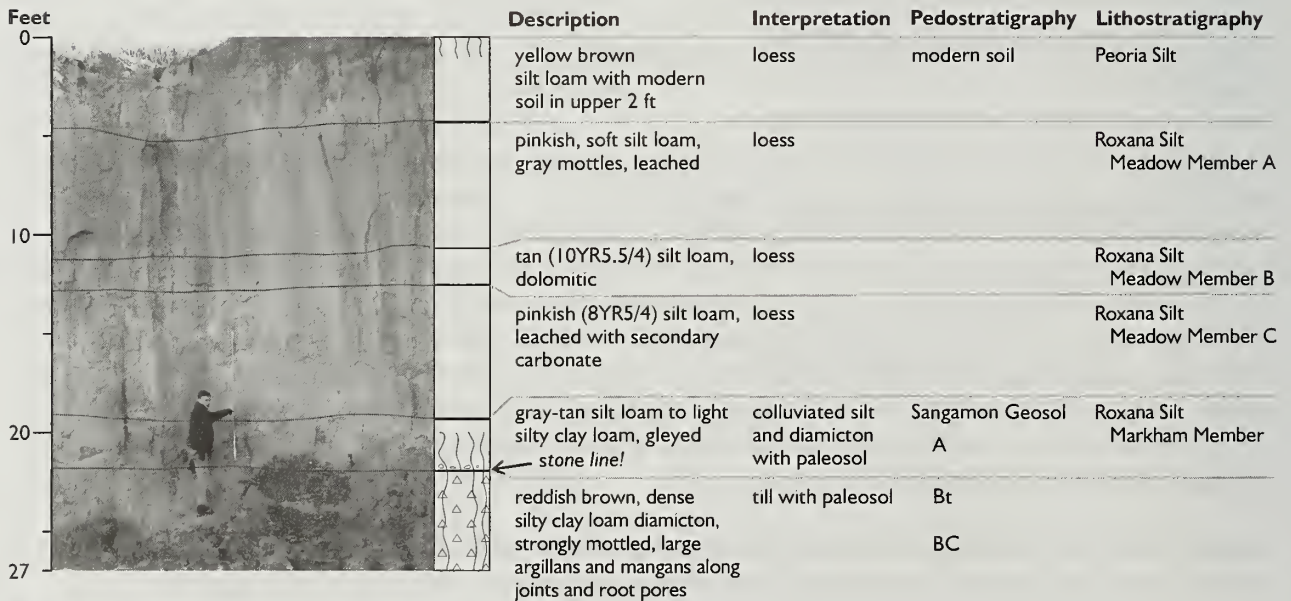


Figure 2-25. Photograph and description of an exposure in the upper La Brot borrow pit.

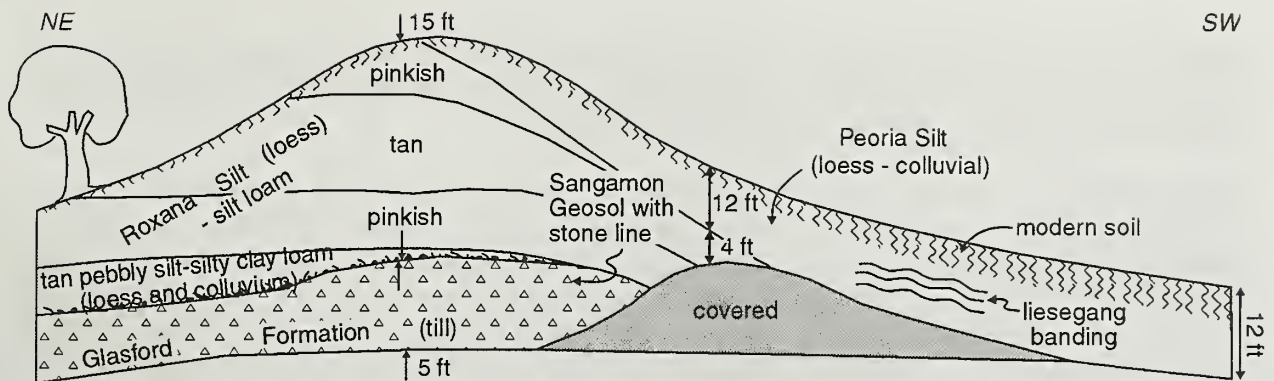


Figure 2-26. Sketch of exposure in the lower La Brot borrow pit. Material properties are similar to those of the upper pit (fig. 2-25), except that calcareous C horizon till is exposed here.

Site Details, Upper Pit The upper pit is cut obliquely into a southwest-facing slope such that the exposure varies from approximately 22 to 33 ft high (fig. 2-25). Unit thicknesses, particularly the uppermost unit, vary across the exposure.

From 0 to 3 ft is a light yellow-brown silt loam, slightly mottled, with the modern soil developed in the top (fig. 2-25). Laterally, this unit thickens to approximately 10 ft. There is a clear lower contact. This part of the exposure is generally inaccessible, but from its visible properties, is interpreted to be loess and is classified as Peoria Silt.

Between 4 and 20 ft is a silty unit distinguished by prominent pink-tan-pink color zonations. From its softness and massive fabric, the unit is interpreted to be loess and is classified as Roxana Silt. The upper pinkish layer, about 7 ft thick, is a soft silt loam, leached, with gray mottles. It has a graded but clear lower contact. The underlying tan (10YR 5.5/4) layer, about 2 ft thick, is a very weakly dolomitic, gray-mottled, silt loam to light silty clay loam with a gradational but clear lower contact. The lowermost pinkish (8YR 5/4) layer is a silt loam to silty clay loam about 6 ft thick. This unit is leached but has secondary carbonate and a gradational lower contact. The lowermost foot of the Roxana Silt is a gleyed silty clay loam with sparse fine gravel clasts. It is leached and contains Mn(?)-cemented krotovina and an abrupt lower contact. The gravel becomes increasingly concentrated downward until it merges with the stone line in the underlying unit. The redox features are attributed to accretion of the A horizon of the Sangamon Geosol during the onset of loess deposition. The origin of the gravel may be from colluviation of underlying diamicton from higher portions of the paleolandscape, bioturbation, or both.

The lowermost 3 ft of the exposure consists of a dense silty clay loam diamicton with distinct mottles and large argillans and mangans along joints and root pores. Clasts include local sedimentary and erratic metamorphic and igneous lithologies. Concentrations of fine gravel, up to 0.5 ft thick, and coarse to fine gravel, one or two clasts thick, form a "stone line" at the upper contact that is gradational with the overlying unit. At nearby sites, correlative diamictons include from a few to many lenses 3–5 ft wide of fine to medium sand. The weathering features are interpreted as Bt to BC horizons of the Sangamon Geosol. The diamicton is interpreted as a subglacial till and is classified as the Glasford Formation. Presumably the till extends down to the underlying Pennsylvanian shale bedrock, as has been observed in nearby outcrops and borings.

Site Details, Lower Pit A complex arrangement of sediment units is exposed in the lower pit at this site. Thickness and properties of the silt units vary considerably across the exposure, and the Illinoian surface has several feet of relief (fig. 2-26).

From the middle of the exposure to the southwest, a light yellow-brown silt loam thickens from 0 to 12 ft toward the creek valley and ultimately forms the entire exposure. The lower contact is subparallel to the modern land surface. The modern soil is developed in the upper 2 to 4 ft of this unit. The lowermost part of the unit is gleyed in the southwest part of the pit. Liesegang banding above the gley is thought to be due to upward-directed wetting fronts from groundwater discharging into the creek valley. This unit is interpreted as loess and is classified as the Peoria Silt.

On the northeast side of the exposure, the modern soil is developed in silt loam that is as much as 15 ft thick and is classified as the Roxana Silt. Color zonations are as prominent as those at the upper pit, but more compressed here. The pink-tan-pink sequence, interpreted as primarily loess, is repeated in the upper 10 to 12 ft. The lowermost portion is a tan, silt loam to silty clay loam with sparse pebbles and is interpreted as colluvial sediment. A prominent stone line at the base of the sequence is subparallel to the modern surface. The stone line is thin and dispersed to the northeast, but thicker and more concentrated in middle of the exposure. Redoxomorphic features are interpreted as a cumulic A horizon of Sangamon Geosol.

The lowest sediment unit is a diamicton that is exposed on the northeast side of the pit but is covered in the middle and cut out to the southwest. Below a clear but gradational contact with the Roxana Silt is about 2 ft of reddish brown silty clay loam to clay loam diamicton. It has a strong blocky structure, large argillans, and mangans along joints and pores. These features are interpreted as the Bt horizon of the Sangamon Geosol developed in till, which is classified in the Glasford Formation. Underlying the Sangamon is 2 ft of C horizon dense, light brown to olive-brown, calcareous silt loam diamicton interpreted as subglacial till.

Discussion In the regional model for loess thickness (Fehrenbacher et al., 1986; McKay 1979b), silt was deflated from the Mississippi River floodplain during westerly storms. Thus, total loess accumulation was greatest (up to 100 ft) at the bluff edge and decreased exponentially eastward to a thickness of 30 ft within about 3 mi of the bluff edge. In uneroded areas, the Peoria Silt is proportionally thicker than the Roxana Silt and thins eastward less rapidly. The La Brot pit lies about 2 mi from the bluff edge, but the total loess thickness is significantly less than predicted, and the Roxana Silt is thicker than the Peoria Silt at this exposure. This difference is attributed to loess erosion concurrent with and subsequent to Peoria deposition in this area of hilly topography. Furthermore, variations in sedimentary features and stratal thicknesses between the upper and lower pit exposures can be attributed to greater erosion during sedimentation near the creek valleys than away from them. Sediments in the upper pit accumulated relatively far from valley slopes in a relatively stable geomorphologic environment.

Modern soil is developed in the Roxana Silt over the northeastern portion of the lower pit (fig. 2-26). From about halfway across the exposure, an erosional surface subparallel to the modern surface truncates Roxana Silt, and overlying Peoria Silt in turn thickens southwestward toward an intermittent creek valley. Gleyed zones and liesegang banding in the Peoria Silt to the southwest reflect the lowered landscape position relative to the water table. These features attest to the influence of slope processes along the creek valley walls and stability of valley configuration over a great span of time.

Pink-tan-pink color zonations in the Meadow Member of Roxana Silt were noted previously by Willman and Frye (1970), McKay (1977), and Grimley et al. (1998) in thick accumulations of Roxana Silt proximal to the Illinois and Mississippi Rivers in southwestern Illinois; these zonations even occur as far south as Crowley's Ridge in Arkansas. McKay (1977, 1979b) suggested that the color patterns may be related to source area variations. He noted that the tan zone (sometimes gray) is generally more illitic and dolomitic in the St. Louis area and thus may have more Paleozoic contributions, perhaps from an ancestral Lake Michigan Lobe. Wood collected from the base of the tan zone, where a sand layer occurs in some places, have been dated 40,000 ¹⁴C yr B.P. (McKay, 1977, 1979b). The upper and lower pink zones were hypothesized to record more contribution from the Upper Mississippi Valley region northwest of Illinois. Although the Lake Michigan Lobe is no longer thought to have been active during Roxana Silt deposition (Curry and Pavich, 1996), changes in provenance may have occurred in response to shifting positions of more northern glacial lobes (i.e., Superior, Wadena, or Des Moines lobes), which are suspected to have been source contributors to the Roxana Silt (Leigh, 1994; Grimley, 2000). Alternatively, pedogenic effects, such as the Farmdale Geosol and earlier pedogenic activity, may be partially responsible for the color and mineralogical changes in the Roxana Silt. The pinker zones are typically more leached of carbonate and contain fewer gastropod shells.

The character of the stone line at the top of the Sangamon B horizon varies across these exposures. Clasts are more concentrated and have a larger maximum size in the lower pit than in the upper pit. In addition, the upper contact of the diamicton is sharper, and the immediately overlying sediment is more pebbly in the lower pit. Stone lines have been attributed to lag deposits on erosional surfaces and bioturbation (e.g., Johnson and Balek, 1991). The relative prominence of the stone line in the lower pit most easily supports an erosional lag interpretation, but the abundant pebbles in the overlying loess supports a colluvial interpretation. These features are expected with increased slope.

Economic Issues Mr. W. La Brot has been selling the loess out of this pit in his backyard for more than 20 years. The hill originally sloped gradually down to where his house is now located. The land surface on the south side of the upper pit exposure follows this slope. The loess is used locally by individuals and city planners for yards, flower berms, shrubs, and fill material.

The value of each load (8 to 8.5 U.S. tons) has increased considerably in recent years because many other borrow operations have shut down in this rapidly urbanizing area. So called "bluff dirt," which is mainly Peoria Silt, sells for \$44 per load today, whereas the underlying "dirt," mainly Roxana Silt, sells for \$40 per load. These prices are about double those of 20 years ago according to Mr. La Brot. The Peoria Silt is the more valuable because its lower clay content makes it drier and more friable than the Roxana Silt. These properties make the Peoria Silt well suited for yards and gardens because it produces a very fine fertile topsoil and is easily spread out. The Roxana Silt from this borrow pit is more often used for fill. Mr. La Brot had at one time been approached by the Illinois Department of Transportation for purchase of the loess for road fill. The relatively high moisture content in the lower portion, however, reduced the value to below that for his other business.

Points to ponder

- *Is the stone line within the Sangamon Geosol erosional, biogenic, or both?*
- *Does the pink-tan-pink horizonation of the Roxana Silt reflect changing provenance of Mississippi Valley floodplain alluvium, or is it pedogenically controlled, or both ?*

Stop 9: Prairie Du Pont Section (Grimley)

French Village 7.5-minute Quadrangle, SE, NW, NE Sec. 21, T1N, R9W, St. Clair County, Illinois.

Overview The Prairie Du Pont Section, exposed in a large cutbank on the south side of Prairie du Pont Creek (fig. 2-27), lies on a highly dissected portion of the Illinoian till plain in the St. Louis Metro East area (figs. 2-2 and 2-4). First discovered in 1998 by Brett Denny (an ISGS geologist), the site exposes a classic sequence of Wisconsinan loesses overlying Illinoian till and lacustrine deposits and a well-exposed Sangamon Geosol.

Site Details The basal 19 ft of this section consists of a locally significant lacustrine unit known as the Petersburg Silt (fig. 2-28). This unit is predominantly crudely bedded silt and is probably composed largely of redeposited loess. The upper 1–2 ft is oxidized olive-brown. Below this, the silt is gray, calcareous, and fossiliferous and contains scattered erratic pebbles, interpreted as dropstones from melting icebergs.

Above the Petersburg Silt is a relatively thin exposure (6 to 10 ft) of Glasford till (loam diamicton) and sandy sorted sediment. Some sand-filled channels are present in the upper and lower portions of the Glasford Formation, deposited during the Illinoian Stage. The Glasford Formation is overlain by about 3 ft of late Illinoian loess that has been significantly altered by the Sangamon Geosol. The well-developed Sangamon Geosol is predominantly reddish brown silty clay loam and is typical of moderate to well-drained interglacial soil profiles, containing numerous clay skins and some mottling. The upper portion of this section (fig. 2-28) consists of the two extensive Wisconsinan loess units (Peoria and Roxana Silts). Some of the Peoria Silt has been truncated along the hillside; total loess thickness is about 30 ft on nearby hilltops, whereas the total thickness here is 15 ft.

Gastropods and Bivalves in the Petersburg Silt Fossils are mainly aquatic gastropods (*Lymnae*, *Gyraulus*, *Pomatiopsis*, and *Catinella*) with some terrestrial genera of gastropods (*Hendersonia*) as well as some aquatic bivalves (*Pisidium* or fingernail clams), all of which range from about 2 to 6 mm in length or width. Identifications were based on photographs in Leonard and Frye (1960) with some identifications by Eric Oches (University of South Florida). *Pomatiopsis* is a genus common in areas of moist land or in shallow water with freshwater plants (Baker, 1931). Terrestrial gastropods, such as *Hendersonia*, were probably washed into the lake. One ostracode species (*Cypridopsis vidua*) identified by B. Brandon Curry (ISGS) also suggests a shallow water environment sourced by groundwater and occasional flooding. Amino acid ratios (alloisoleucene/isoleucene peak heights) on gastropod (*Pomatiopsis* and *Catinella*) and bivalve (*Pisidium*) shells from the Petersburg Silt are generally in the range of 0.16–0.19 (courtesy of Eric Oches, University of South Florida, 1999). These results are typical for Illinoian Stage deposits in the region (Miller et al., 1994).

Oriented Spruce Logs in the Petersburg Silt During repeated visits to the site in 1998 and 1999, several spruce (*Picea*) wood fragments (identified at the U.S. Department of Agriculture Wood Anatomy Research Lab, Madison, Wisconsin) were found scattered throughout the Petersburg Silt (fig. 2-29). Large spruce logs, 4 to 5 ft long and several inches in diameter, found in basal portions of the silt, were oriented in a similar direction, perhaps parallel to a paleocurrent direction. The considerable thickness of fine-grained lacustrine sediment and diamicton was conducive to excellent preservation of the logs. Many logs have intact bark (fig. 2-30), suggesting

a lacustrine environment with only very slow-moving waters (consistent with a slackwater environment).

Slumping A large slump block at the center of this exposure (fig. 2-31) appears to have failed at approximately the level of the Sangamon Geosol. At this depth, below about 15 to 25 ft of loess, the higher clay content and more poorly sorted character of the Sangamon Geosol (developed into diamicton and silt) act as a relatively impermeable zone to groundwater flow and infiltration. The Sangamon Geosol solum is commonly close to the local water table level, or just above it in this case, thus forming a perched water table level. In either scenario, higher pore water pressures and the additional weight of the water acting on these type of steep slopes are the combination of factors that often lead to slumping in thick loess deposits.

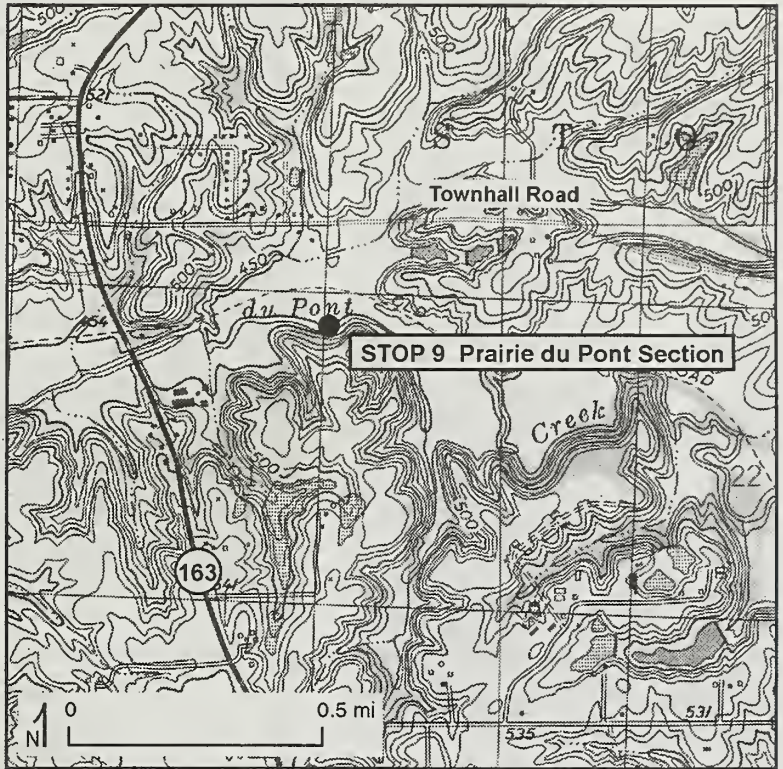


Figure 2-27. Location of the Prairie du Pont Section in a portion of the French Village 7.5-minute Quadrangle.

The oversteepening of the bank caused by the erosion into this cutbank by Prairie du Pont Creek was the “last straw,” triggering the slumping of this block, which was previously in a marginally stable condition. This type of slumping is very common in the region, particularly in loess deposits. This process is discussed more completely by Su elsewhere in this guidebook.

Points to ponder

- *Are fossils in the Petersburg Silt representative of the peak glacial environment of the Illinoian Stage?*
- *Could erratic pebbles in the Petersburg Silt have been eroded from uplands that might have been glaciated in the pre-Illinoian, or are they dropstones from icebergs backed up Prairie du Pont Creek from the Mississippi Valley or from concurrent ice on uplands?*

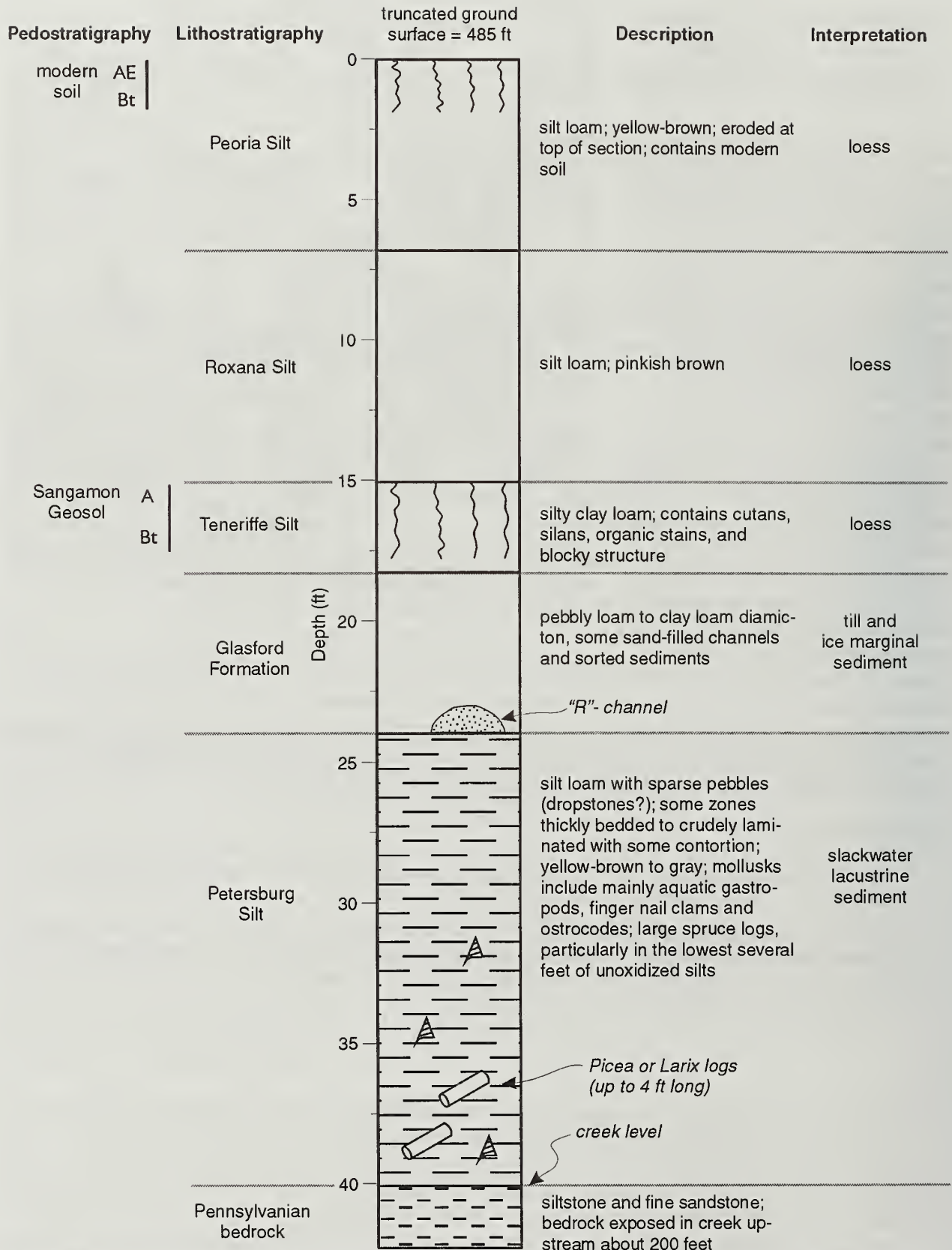


Figure 2-28. Stratigraphic column summarizing findings at the Prairie du Pont Section. The section was described in November 1998 and in October 2000. The elevation is approximately 485 ft at the section top.



Figure 2-29. View of the lower portion of the Prairie du Pont Section, showing the Petersburg Silt with its vague laminations, sparse distribution of pebbles, and wood fragments.

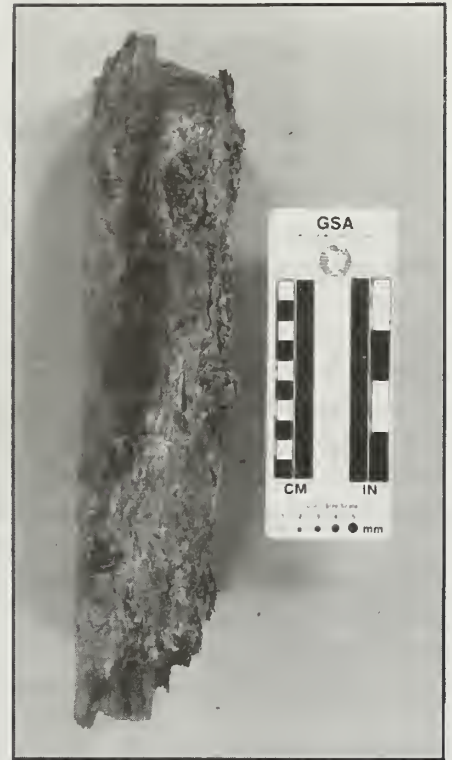


Figure 2-30. Close-up view of a well-preserved spruce (*Picea*) log with preserved bark from the Prairie du Pont Section, suggesting very still lacustrine conditions.



Figure 2-31. View of a slump block in the distance at the Prairie du Pont Section. The Petersburg Silt can be seen at the base of the section in the lower right, with loess exposed in the upper one-third of the outcrop. The Sangamon Geosol and Glasford Formation are covered with colluvial material in this photo.

ACKNOWLEDGMENTS

We thank Andy Stumpf and Christine Wiscombe for help with field work at the sites visited on this trip. Discussions with Brandon Curry, Ardith Hansel, and Don McKay have also been very helpful. Dick Baker and Brandon Curry analyzed the plant macrofossils and ostracodes, respectively, from two sites. Herb Glass and Philip DeMaris analyzed the clay mineralogy of many samples. We also thank the landowners and quarry operators who allowed us on their property to view the Quaternary deposits for this trip. These include Harold Valstead (Kane Quarry); Tom Thompson, Wildflower Inn Bed and Breakfast (Mason Hollow Section); Steve Velsor, Lockhaven Country Club (Piasa Creek Terrace); the Lohr family (Lohr Quarry); Stanley Gardocki (Dunn Road Section); Chuck Walker and the Keller family (Keller Farm Section); Willard La Brot (La Brot Section); and Richard Waelti (Prairie du Pont Section). David Malone, Skip Nelson, Ardith Hansel, Jonathan Goodwin, and Cheryl Nimz provided helpful review comments. David Malone also helped coordinate the field trip logistics.

The description of the Quaternary geology of the St. Louis Metro East area (pages 21–31) and the information contained in Stop 9 (pages 60–63) were previously published in ISGS Guidebook 32.

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ENGINEERING PROBLEMS CAUSED BY LOESS IN THE ST. LOUIS METRO EAST AREA

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Loess, which constitutes a significant part of the surficial materials in the uplands of the Metro East area, is often difficult to manage when used as an engineering material. The engineering problems associated with loess are caused by its unconsolidated nature, uniformly small particle size, and unusual engineering properties (Table 2-4).

The stability of loess deposits is strongly related to several geotechnical properties: in situ bulk density, natural moisture content, Atterberg limits, and erodibility. Generally, loess has relatively low bulk density and low to moderate compressibility. Some loess may be collapsible. Because of its low clay content, which serves as the principal binder material, most loess is virtually non-plastic. Because of some binding by clay, loess has a moderate shear strength, has moderate bearing capacity, and is normally stable when dry. However, water saturation causes loess to become unstable by reducing its shear strength to extremely low levels. Loss of compressive and shear strength upon wetting is largely the result of softening and swelling of the clay, which is its primary cementing agent.

Major engineering problems associated with loess are (1) slumping and sliding failures in its primary, (2) foundation failures in houses and structures, and (3) erosion.

Slope Problems

Engineering properties of loess are highly dependent on its water content. Loess has unusual shear strength and assumes a nearly vertical angle of repose as long as it remains relatively dry. As shown in figure 2-32, the design of roadcuts can utilize this unique loess property. Vertical cuts can be constructed in loess above the water table, but gentle slopes with porous retaining structures must be constructed where loess is below the water table to ensure a stable embankment. The construction of ponds, excessive watering of lawns, and use of septic tanks and fields may cause loess to become saturated and cause slope stability problems.

Table 2-4: Engineering geology properties of loess deposits in the St. Louis Metro East area.

Particle size	
Sand, %	0–5
Silt, %	65–95
Clay, %	5–25
Thickness, ft	15–100
Slope	level to steep
Bearing capacity	low to moderate
Frost/heave	high
Erodibility	high
Water table	high to moderate
Permeability	high to moderate
SPT (blow)	3–13 (avg. 7)
Compressive strength, tsf	0.4–1.6 (avg. 1.0)
Natural water content, %	20–33 (avg. 26)
Liquid limit	28–47 (avg. 32)
Plastic limit	22–30 (avg. 26)
Plastic index	2–17 (avg. 6)

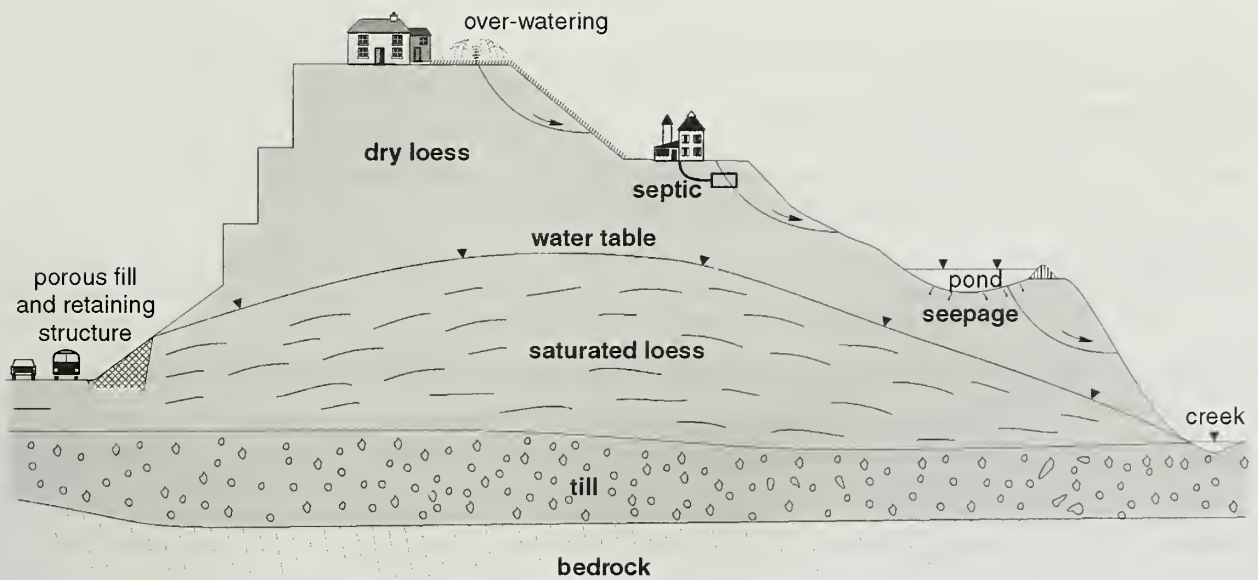


Figure 2-32. Typical slope stability problems in loess (modified from DuMontelle et al., 1971).

Saturation of the Roxana Silt is responsible for most of the slope failures in the area. This saturation is likely a result of a perched water table formed on top of the more clayey Sangamon Geosol, which commonly has a clay content of about 30% in B horizons and is typically developed into till in this region. In addition, because the Roxana Silt has a slightly greater clay content than does the Peoria Silt, surface water that percolates downward easily through the Peoria loess can also form a perched water table at the contact of the two loess units. Other potential perched water tables may form at contacts with Pennsylvania shales. These perched water tables not only cause slope failures, but also initiate soil creep on steep slopes of 20% or more.

Foundation Problems

Loess is a suitable foundation material when dry but not when wet. Its most unfavorable characteristic, loss of compressive and shear strength upon wetting, is often difficult for foundation engineers to manage. Typical foundation problems include excessive and uneven foundation settlements. Methods used to overcome these problems include compaction, chemical grouting, reinforcement, employment of geomembranes, special drainage system, terracing, and grassing. For more information and discussion, please refer to Evstatiev (1988).

Erosion Problems

When stripped of vegetative cover, loessal soils are subject to rapid erosion. Removing vegetative cover in the early stage of subdivision development allows gullies to form and causes siltation downstream. A more serious type of erosion that often goes undetected is subsurface erosion that takes place under streets and foundations. Loess is easily eroded and transported by water seeping through soil as well as by flowing on the surface. When water is allowed to flow under a structure, the silt and clay size particles of soil are removed. Initially this process, known as piping, is slow and insignificant, but increases rapidly once started. If allowed to continue, piping can cause a significant loss of foundation support.

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AMINOSTRATIGRAPHY OF THREE PLEISTOCENE SILTS IN THE COLLINSVILLE-BELLEVILLE AREA, ILLINOIS

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Amino acid geochronology has been successfully applied in the stratigraphic correlation of Pleistocene loess and other silt units in the Mississippi Valley (e.g., Clark et al., 1989; Mirecki and Miller, 1994). New exposures and drill cores of fossiliferous Illinoian Petersburg Silt and Chinatown Silt, plus the Wisconsinan Roxana Silt and Peoria Silt, afford new opportunities to test the ability of amino acid racemization data to correlate and distinguish among these four silt units in west-central Illinois. Previous aminostratigraphic investigations in the region have been based on epimerization of the amino acid isoleucine to its non-protein diastereoisomer alloisoleucine. The alloisoleucine/isoleucine (A/I) ratio is a measure of the age and post-depositional temperature history of the fossil mollusk shells on which the measurements are made.

Results presented in Table 2-5 show racemization data for two different amino acids: aspartic acid (Asp), which racemizes relatively rapidly, and glutamic acid (Glu), which racemizes relatively slowly, similar to isoleucine. Samples were analyzed using reverse-phase liquid chromatography following methods described by Kaufman and Manley (1998). Results of these analyses suggest that the ratios of D-Asp/L-Asp allow researchers to be able to differentiate between the Peoria and Roxana Silts, which cannot be differentiated using D-Glu/L-Glu and A/I (Clark et al., 1989). Both D/L pairs

Table 2-5: Results of amino acid analyses in common gastropod genera from four Pleistocene silt units in west-central Illinois.

Lab no.	Genus	D-Asp/L-Asp	D-Glu/L-Glu
Peoria Silt—Keller Farm Section, Collinsville, Illinois			
FAL-0314	<i>Succinea</i>	0.317 ± 0.044 (12) ¹	.064 ± 0.011 (12)
Roxana Silt—Schoolhouse Branch Section, Collinsville, Illinois			
FAL-0307	<i>Succinea</i>	0.410 ± 0.067 (2)	0.074 ± 0.004 (2)
Petersburg Silt—Prairie Du Pont Section, Belleville, Illinois (Stop 9)			
[outcrop FRV-15F]			
FAL-0116	<i>Catinella</i>	0.566 ± 0.042 (2)	0.235 ± 0.021 (2)
FAL-0117	<i>Pomatiopsis</i>	0.613 ± 0.042 (2)	0.260 ± 0.014 (2)
Petersburg Silt—Southwestern French Village Quadrangle, Belleville, Illinois			
[core FRV-2-123']			
FAL-0194	<i>Pomatiopsis</i>	0.534 ± 0.015 (2)	0.158 ± 0.018 (2)
[core FRV-1-95']			
FAL-0192	<i>Pomatiopsis</i>	0.575 ± 0.024 (3)	0.194 ± 0.006 (3)
Petersburg Silt—Powdermill Creek Section, Belleville, Illinois			
FAL-0336	<i>Succinea</i>	0.577 ± 0.041 (5)	0.210 ± 0.036 (5)
FAL-0341	<i>Succinea</i>	0.592 ± 0.105 (4)	0.178 ± 0.051 (4)
FAL-0338	<i>Pomatiopsis</i>	0.548 ± 0.063 (8)	0.205 ± 0.023 (8)

¹Values are means ± standard deviation (number of analyses).

can be used to distinguish between Wisconsinan and Illinoian units. The Petersburg Silt and Chinatown Silt of McKay (1979) cannot be distinguished on the basis of D/L ratios; the two units are either very close in age, or they represent sedimentation during the same glacial episode.

Three samples of gastropod shells from the Petersburg Silt were submitted by David Grimley, ISGS, for amino acid analysis. Sample FRV-15 was from the Prairie Du Pont Creek outcrop, and FRV-1-95' and FRV-2-123' were collected from drill cores nearby in the French Village Quadrangle. The D-Asp/L-Asp and D-Glu/L-Glu values measured in shells of the gastropod genus *Pomatiopsis* suggest that samples collected from silt exposed in the creek cutbank may be slightly older than those recovered from drill cores. Samples collected from the Chinatown silt yield D/L ratios comparable with those from Petersburg Silt drill cores. With measurements on additional gastropod genera and from additional silt units, a comprehensive aminostratigraphy can be developed for the stratigraphic correlation and relative age evaluation of silt units throughout the region.

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URBAN EROSION IN MADISON COUNTY

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Soil erosion is a major problem in Madison County, a predominantly urban county in southwestern Illinois. Soil erosion is one of the greatest threats to the nation's productivity and the largest source of pollutants to our waterways. Many years ago, farmers were primary contributors to soil erosion by not investing in the soil through crop rotation or the addition of manure or other nutrients. Because land was cheap and plentiful, those investments did not seem to be a good economic decision when one could simply farm elsewhere when the soil became depleted of nutrients and organic matter. In recent years, the farming community has learned valuable lessons about the effects of soil erosion, and erosion mitigation practices are now commonplace.

Today, in a time of growing populations and expanding cities, shopping centers, and major highways, an additional challenge is to reduce the amount of erosion from the urban sources that are increasingly replacing formerly rural landscapes. During rain events, impervious surfaces such as rooftops, sidewalks, roads, and parking lots prevent stormwater and runoff from naturally seeping into the ground. Rainwater subsequently runs across these surfaces until it can soak into the ground or find some way to a local stream, often causing erosion along the way. The increased flow of water to stream channels at faster rates can widen streams by increasing bank erosion, can degrade habitat structure, can decrease the stability of the channel, and can fragment the tree canopy that holds soil in place along stream banks.

Four main properties determine a soil's erodibility: texture, slope, structure, and organic matter content. Although texture is probably the most important of these properties, texture is also an inherent soil property that is impractical to change. Much of the soil in Madison County is formed in materials that are high in clay and especially in silt content, and thus the soil erodes very easily. Following erosion, the silt portion of the soil settles out in roads, ditches, ponds, and lakes and causes siltation problems. Clay particles stay in suspension, causing bodies of water to be turbid.

Loess soils, which contain predominantly silt-sized particles, occur on all uplands in the area but are especially prevalent in bluff areas. The Natural Resources Conservation Service (NRCS) has worked with many individuals and groups on erosion problems in these areas. For example,

Southern Illinois University at Edwardsville, located on the bluffs east of the town of Wood River, has installed detention basins in upstream locations on the university property in order to both slow runoff and reduce sedimentation in the creeks. The detention basins provide temporary storage for stormwater and associated runoff and release water at a much slower rate. These detention basins have trapped a significant amount of sediment, and high flows seem to have been reduced downstream. The NRCS is also working with the U.S. Army Corps of Engineers to identify and restore wetlands in the American Bottoms to temporarily store floodwaters. The shallow water areas proposed can take on and store the additional runoff to reduce flooding tendencies.

There are means of better holding the soil in place and reducing runoff, but these issues are still enormous problems to manage. We must strive to implement erosion control plans and carry them out before development occurs if we hope to keep the soil in place. The soil is a valuable resource that we do not want to lose!

Sequence Stratigraphy of Pennsylvanian Cyclothem Strata of Central Peoria County, Illinois

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INTRODUCTION

The cyclothem of Harold Wanless and J. Marvin Weller (1932) are prominent, if not famous, features of the Middle and Upper Pennsylvanian strata of the Illinois Basin. These stratigraphic successions, which are akin to depositional sequences, are underutilized for stratigraphic and mapping purposes. This field trip examines Middle Pennsylvanian (Desmoinesian Stage/Westphalian D Series) strata near the area where Wanless developed the cyclothem concept, as well as near the site of the earlier studies of cyclic deposition of Udden (1912). Topics to be discussed on this field trip include (1) how cyclothem deposition fits within "Slossian" sequence stratigraphy, (2) whether a standard lithostratigraphic hierarchy is possible for cyclothem strata, (3) possible alternative approaches to cyclothem stratigraphy, and (4) local and regional sedimentologic and stratigraphic characteristics of the strata.

The stratigraphic interval of the outcrops encountered on this field trip ranges from just below the Houchin Creek Coal to just above the Danville Coal. Since 1960, most of this interval (except for the stratum above the latter coal) has been placed within the Carbondale Formation of Illinois as defined by Kosanke et al. (1960). Several recent reports, however, have used different formational boundaries (Nelson et al., 1991; Nelson, 1995a), and one report (Nelson, 1995b) simultaneously utilized two different beds for the lower boundary. All of the named stratigraphic units in this guidebook are formal members of the Carbondale Formation (for a general reference, see Hopkins and Simon, 1975). For brevity, the term "Member" is omitted throughout this guidebook.

ROAD LOG AND SITE DESCRIPTIONS

The road log begins at the northern junction of Interstates 74 and 55, northwest of Normal, Illinois. Moraine identification was derived from the maps of Willman and Frye (1970) and Grimley and Andrew (2000).

Proceed west on I-74. Between the junction and Congerville, the route parallels the edges (right side; northeast) of (1) the Normal Moraine (right side; northeast) and then (2) the overlapping Eureka Moraine. Just after MP 117, the road turns west away from the moraines. Cross the Mackinaw River at MP 113.5. At MP 110, the Bloomington Moraine is in view to the south. Just after MP 108, the route begins to ascend the Bloomington Moraine. The top is at about MP 106, and the outer edge is reached just before the Morton village limits (MP 104). Take Exit 99 onto I-474 west (left). Between here and the Illinois River valley, the route crosses the LeRoy and (overlapped) Shelbyville Moraines, the latter of which is the terminal moraine of the Wisconsin glacial episode. Cross the Illinois River at about MP 8.6 (I-474). At MP 3.5 (I-474), the Brereton

Limestone crops out on the south side (left) of I-474. Merge with I-74 west (Exit B). Exit from I-74 at Exit 82; turn north (right). Enter Kickapoo Village. Turn left (west) onto US-150. Turn right (north) onto Princeville-Jubilee Road. Turn left (west) onto Jubilee College Road. Turn right (north) just before the entrance to the Jubilee College Historical Area. Descend the hill, cross the ford over Jubilee Creek, and park along the road.

Stop 1: Jubilee Creek Ford

Property Owner State of Illinois.

Location Oak Hill 7.5-minute Quadrangle. NE/4, NW/4, SE/4, Sec. 26, T10N, R6E. Outcrops will be examined in two locations: a high cutbank along Jubilee Creek (UTM 265470E, 4522220N) and exposures along a tributary adjacent to the park road (UTM 265565E, 4522160N). (All Universal Transverse Mercator locations are in zone 16, 1927 North American datum.) The composite stratigraphic column (fig. 3-1) is based on data measured at both sites.

General Stratigraphy Houchin Creek (a.k.a. Summum or No. 4) Coal, Excello Shale, Covell Conglomerate, Springfield (a.k.a. No. 5) Coal, Turner Mine Shale, and Canton Shale.

Description At this first stop, we will discuss the overall stratigraphic concepts that have been applied to cyclic Pennsylvanian strata in the Illinois Basin. Most of the formally named units will be discussed in detail at later stops rather than here. The Jubilee Creek exposure is the thickest exposure examined on this field trip, although slumping has covered much of the outcrop since a previous field trip on the Middle Pennsylvanian of the region (Smith et al., 1970).

The cyclothem, as conceived by Harold Wanless and J. Marvin Weller (1932) and based on earlier studies by Udden (1912), dominated stratigraphic studies of Pennsylvanian strata in the Illinois Basin from the 1930s to the 1960s. The cyclothem was formally defined by Wanless and Weller (1932) as a “series of beds deposited during a single sedimentary cycle of the type that prevailed during the Pennsylvanian period.” A cyclothem thus constituted an unconformity-bounded, terrestrial-to-marine succession that was based generally on eight units, as previously described by Weller (1930):

Marine strata:

- Shale with siderite nodules
- Marine limestone
- Calcareous shale
- Black fissile shale

Terrestrial strata:

- Coal
- Underclay
- Arenaceous shale

Sandstone, unconformable base.

At this exposure (fig. 3-1), the upper part of the Summum Cyclothem and most of the St. David Cyclothem are exposed.

The disconformable base of sandstones was selected as the boundary between cyclothem because Weller (1930, 1931) considered the formation of the unconformity to have resulted from diastrophism. At that time, prior to the introduction of separate time, time-rock, and rock classifications, obvious angular and erosional unconformities were considered as the most suitable features for subdividing geologic time and the rock column. Weller (1930) also attributed to diastrophism the transgression of seawater over peat swamps. It is worth noting that Weller (1930) also considered the marine transgressive surface to have merit as a bounding surface between cyclic units.

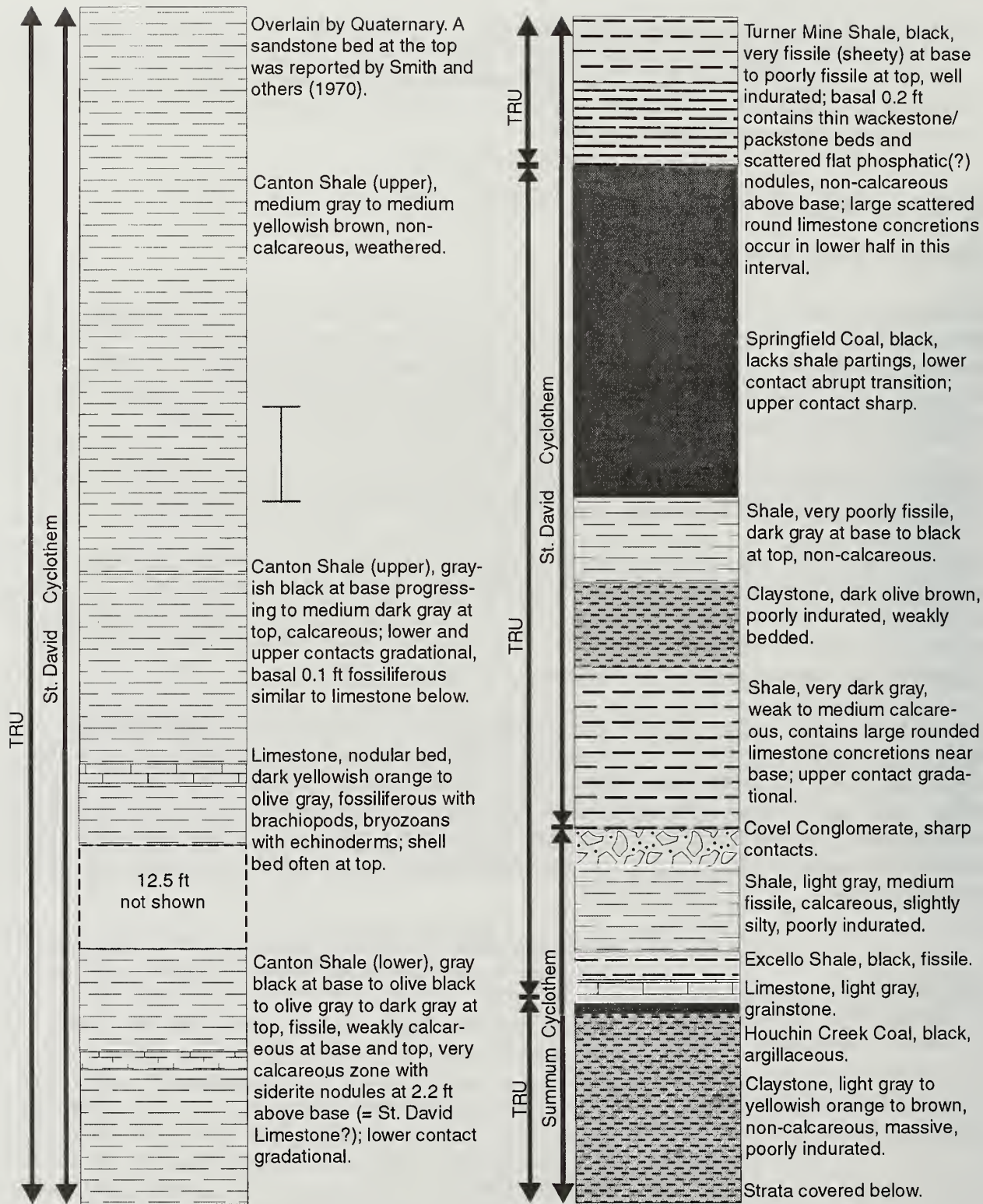


Figure 3-1. Stratigraphic column of strata exposed at Stop 1. TRU, transgressive-regressive unit. Lithological symbols used on the stratigraphic column are explained in figure 3-9. Vertical scale bar equals one foot.

The cyclothem concept and its application to Pennsylvanian strata in the Illinois Basin parallels current concepts of sequence stratigraphy. Wanless and Weller's (1932) definition of a cyclothem emphasized the premise that strata within a single cyclothem were related genetically, having been deposited within one sedimentation cycle. The boundary separating cyclothem, the disconformity at the base of the sandstone, was considered to be the most chronostratigraphically significant unconformity within the succession (Weller, 1930, 1931). Thus, cyclothem are unconformity-bounded stratigraphic units, defined with criteria similar to those for defining cratonic sequences, and differing only in scale (Sloss, 1963, 1988). Cyclothem are similar to sequences in that both can be interpreted to have been deposited between eustatic-fall inflection points (Posamentier et al., 1988). Cyclothem are unconformity-bounded stratigraphic units that are debatably equivalent to a depositional sequence. A depositional sequence is defined as a "relatively conformable succession of genetically related strata bounded at its top and base by unconformities" (Mitchum et al., 1977; Haq, 1991). The debatable aspect is whether or not all of the units within a cyclothem are genetically related.

Kosanke et al. (1960) dropped the cyclothem-based lithostratigraphic classification (Wanless, 1956) because of a perceived requirement that all lithostratigraphic units needed to be differentiated into formations characterized by gross lithologies. The strongest argument against the use of cyclothem classification was that the disconformity between cyclothem was generally difficult or impossible to recognize both in surface and subsurface mapping in areas between incised valleys or channels. At this exposure (figs. 3-1 and 3-2), Wanless (1957) placed the cyclothem boundary at the top of the Covell Conglomerate instead of at the base of a sandstone. Details on the Covell Conglomerate will be discussed at a later field trip stop. A second argument against cyclothem as the basis for classification was that the base of sandstones was not considered to be an adequate stratigraphic horizon for mapping structural and economic geology. Kosanke et al. (1960) also considered the mapping of economically significant beds (coal, limestone, and shale) to be a major mapping objective. Mapping of these beds was preferred to mapping the disconformity.

Kosanke et al. (1960) replaced cyclothem formations with much thicker, key-bed-bounded formations. The perceived gross lithologic differences between most of these formations, however, were overstated. Although the principal lithology of all the Pennsylvanian formations is shale (by more than 50%) and although sandstone plus shale constitutes more than 85% of the Pennsylvanian rocks, the lithologies that were used to differentiate the formations were the coal and limestone beds, which constitute only between 3 and 12% of the gross composition. This usage is inconsistent with the *International Stratigraphic Guide* (Hedberg, 1976), which prefers that lithostratigraphic units consist of a specific dominant lithologic type or a combination of dominant lithologic types (shale and sandstone, in this situation). Although Kosanke et al. (1960) attempted to define the formations based on distinct differences in internal lithologies, the formations were bounded by marker beds, consisting of either coal or limestone, and the differences in gross internal lithologies are more perceived than real. Defining and differentiating formations based on gross lithologies works well with most sedimentary strata. The use of such formations, however, is not very feasible for detailed studies of the Middle and Upper Carboniferous of the Illinois Basin where the strata characteristically are composed of hundreds of mostly thin lithologic units. The gross lithologically based formations are suitable for regional studies, but are generally too thick for studies of smaller areas (e.g., 7.5-minute quadrangles).

My studies of Carboniferous strata at various sites in the Illinois Basin indicate, however, that an alternative exists that is useful from both the mapping and sedimentological perspectives and is



Figure 3-2. View of the Covell Conglomerate exposed in a cutbank along the tributary adjacent to the park road. The head of the hammer marks the contact between the conglomerate and the overlying dark shale. This contact is a relatively smooth surface, although the lithological change is sharp and distinct. The underlying contact, however, is noticeably uneven and indicates erosion of the underlying shale bed prior to deposition of the conglomerate. Wanless (1957) placed the boundary between the Sumnum and St. David Cyclothems at the top of the conglomerate.

applicable to both regional and detailed studies. It should be stressed that this alternative was constructed because the unconformable boundaries of cyclothems, as defined by Wanless and Weller (1932), could not be traced regionally, or even locally, in most of the areas where I have worked (Weibel, 1988, 1991). The reason that the cyclothems could not be recognized is that the depositional model of the Wanless and Weller (1932) cyclothem contained a significant shortcoming (Weibel, 1996). The cyclothem inexplicably contained two significant disconformities: the disconformity under the basal sandstone and the disconformity marked by the paleosol “underclay” of the middle portion. [“Underclay” is placed in quotations because not all fine-grained strata beneath coals are claystones and claystones derived from soil formation are present in many places without an overlying coal (Hughes et al., 1987)]. In the revised, generalized stratigraphic model (fig. 3-3), the traditional basal sandstone disconformity was formed in channels during regression and valley incision. The “underclay” paleosol simultaneously developed in intervening areas between valleys and channels. The distal equivalent of the disconformity at the base of the channel-filling sandstone is the disconformity recorded by the “underclay” paleosol. The differing sedimentological origins of the two types of disconformity constrain, on a regional basis, their lateral extent; the sand-filled channels generally occur as linear patterns, whereas the paleosol “underclays” occur in large areas between the channels. “Underclay” units, however, are generally difficult to recognize, particularly where thick coal beds are absent. After it was determined that neither the basal sandstone nor the “underclays” were suitable for stratigraphic control, the marine units were utilized instead (Weibel, 1988, 1991, 1992, 1996; Weibel et al., 1989). Marine units have long been recognized as widespread key beds in the Middle and Upper Pennsylvanian rocks of the Illinois Basin (Wanless, 1939). Marine units crop out in many places, are recognizable on most geophysical logs, are more continuous laterally than sandstone units, and are more numerous than coal beds in the stratigraphic column. At this site, the marine beds include black fissile shale (e.g., Turner Mine Shale; figs. 3-1 and 3-4), limestone (e.g., unnamed limestone above Houchin Creek Coal; figs. 3-1 and 3-5), and gray calcareous shale.

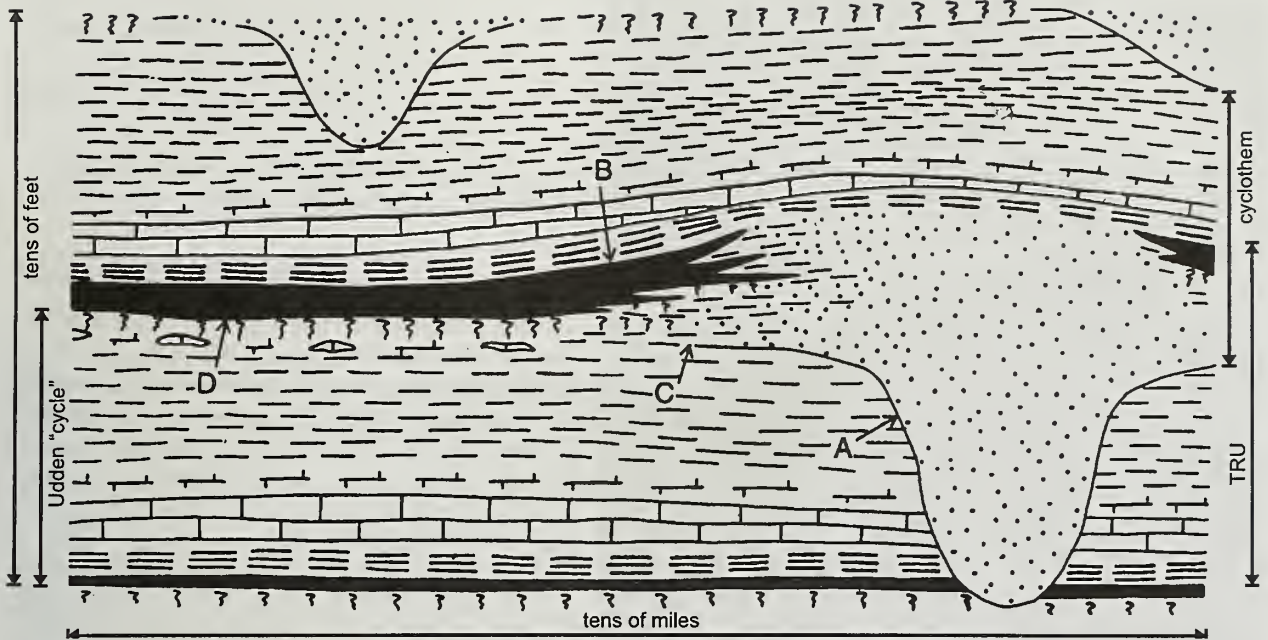


Figure 3-3. Schematic cross section of Middle Pennsylvanian strata in the Illinois Basin showing several cycles of sedimentation. The base of coal is the boundary between the “cycles” of Udden (1912). The base of the sandstone channel is the boundary between cyclothems of Wanless and Weller (1932) and is equivalent to a depositional sequence boundary. The base of marine strata is the boundary between transgressive-regressive units. A, disconformity below coal “underclay” contains a paleosol; B, disconformity in transition area near channel where deposition and soil formation are intermittent; C, disconformity at base of sandstone channel; D, marine-flooding surface; TRU, transgressive-regressive unit. Note the large vertical exaggeration. Modified after Weibel (1996).

Recognizing the value of utilizing the base of the marine strata as a mapping boundary led toward the informal recognition of the marine-to-terrestrial succession as a useful stratigraphic unit for mapping the Middle and Upper Pennsylvanian rocks (Weibel, 1988, 1991, 1992, 1996; Weibel et al., 1989). This succession constitutes a transgressive-regressive unit (figs. 3-1 and 3-3), which is an informal stratigraphic unit consisting of the lithologic units deposited within a transgressive-regressive depositional cycle. The boundary between successive transgressive-regressive units is the marine-flooding surface at the base of the transgressive marine strata (fig. 3-1). These transgressive-regressive units are laterally continuous genetic units that constitute a natural framework for lithostratigraphic classification and for both local and regional correlations. Transgressive-regressive units fit within a sequence stratigraphic framework because much of the Upper Carboniferous strata in the basin are characterized by multiple transgressive and regressive events. Within this framework, depositional sequence boundaries (“underclays” and basal unconformable sandstones) generally alternate vertically with marine flooding surfaces (fig. 3-1).

Road Log Turn around and retrace the route back to Princeville-Jubilee Road. Turn left (north). Turn left (west) onto Brimfield-Jubilee Road. Turn right (north) onto Maher Road. Turn right (east) onto Martin Road. Drive to the end, turn around, and park.



Figure 3-4. View of the Springfield Coal and Turner Mine Shale exposed in a cutbank along the tributary adjacent to the park road. The head of the upper hammer marks the contact between the coal and the black, fissile Turner Mine Shale. This shale, like the Excello, contains large limestone concretions, particularly near the base, but they cannot be seen in this view. This exposure of the Springfield Coal displays a thickness and lack of shale partings that are typical for the area. The head of the lower hammer marks the contact of the Covell Conglomerate, poorly exposed here, and the shale-“underclay” succession below the coal. The contact between the Turner Mine Shale and the Springfield Coal marks the base of the succeeding transgressive-regressive unit.



Figure 3-5. View of the Houchin Creek Coal, an unnamed limestone, and the overlying Excello Shale exposed in the tributary adjacent to the park road. The coal crops out in the water, and its top is marked by the head of the hammer. The hammer lies across the thin unnamed limestone, which occurs locally at the base of the overlying, black Excello Shale that contains large, limestone concretions. These large concretions are common at the few exposures of the Excello in the field trip area and at the exposures reported by Wanless (1957). The base of the unnamed limestone bed marks the boundary between transgressive-regressive units.

Stop 2: Martin Road

Property Owner Private.

Location Oak Hill 7.5-minute Quadrangle. NW/4, NW/4, NW/4, Sec. 17, T10N, R6E. Exposures on east side of southward flowing creek (UTM 259840E, 4526640N).

General Stratigraphy Herrin (a.k.a. No. 6) Coal, containing the “blue-band” parting and “white top,” and the Brereton Limestone.

Description At this stop we examine the boundary between transgressive-regressive units, the laterally widespread blue-band parting, and the very unusual white-top deposits.

The contact between the Herrin Coal and the overlying calcareous shale/Brereton Limestone succession is a boundary between two transgressive-regressive units (assuming that the white top is of non-marine origin). The marine transgression is marked by the thin calcareous shale between the Herrin Coal and the overlying Brereton Limestone (figs. 3-6 and 3-7). Weller (1930) had considered the contact between coal beds and the overlying marine units to be suitable for differentiating cyclical units (equal to formations). Because he (incorrectly) thought that marine beds do not succeed all coals in most areas, this boundary was deemed not satisfactory for use throughout the Pennsylvanian column. Most coal beds in the Illinois Basin, however, are succeeded by marine strata and, particularly in the Upper Pennsylvanian, where coal beds are very thin or absent, marine strata occur more commonly than coal in the stratigraphic column.

In this area of Peoria County, the lithology of the marine strata overlying the Herrin Coal is laterally variable. At this site, the coal and the white top are succeeded by marine strata consisting of the calcareous shale and the Brereton Limestone. About 0.25 mi to the northeast, the coal crops out in a ravine where, on the east side, the succeeding marine bed is the Brereton Limestone, and, to the west (a distance of about 50 ft), the coal is succeeded by the black, fissile Anna Shale and the Brereton is absent. Outcrops about 1 mi to the west-southwest display a similarly striking lateral variation, but are not as well exposed, and the outcrops are farther apart. White-top deposits are absent at both of these sites.

The environments of deposition of the apparently laterally diverse marine strata are not well understood. Heckel (1977, 1986) has advocated that differences in depth of water and oxygen levels in the water are the primary factors in the deposition of the anoxic black shales to oxic gray limestone. An opposing view was offered by Merrill (1975) who interpreted the lithologic changes to be the result of lateral facies changes in contemporaneous strata. These interpretations are worth comparing with a study by Smith et al. (1970) of a highwall exposure from the Banner Mine (now closed) in Fulton County. At the Banner Mine, the Colchester Coal (a.k.a. No. 2) bed broadly undulates with up to 20 ft of vertical relief. The undulation apparently was a reflection of the depositional topography. The succeeding marine strata consist of the Mecca Quarry Shale (black, fissile) and the Oak Grove Limestone. At the topographic highs, the Oak Grove locally occurs as a 5-ft thick lens, and the Mecca Quarry Shale thins significantly and may be locally absent. Similar situations in this area may be responsible for the lateral variations in the marine strata above the Herrin Coal.

The “blue band” is a miner’s term for a shale parting that occurs within the Herrin Coal throughout most of the Illinois Basin. This parting generally occurs in the lower one-third to one-half of the coal seam and is up to 0.25 ft thick in this area (figs. 3-6 and 3-8). The origin of the blue-band parting has not been clearly established. Hoehne (1957) and Wanless (1957) speculated that the parting could be due to a widespread volcanic ash deposit. Back (1986), however, suggested that the parting is of a detrital, non-volcanic origin because of the absence of mineralogical data indicative of a volcanic ash fall. Wanless (1964) later suggested a fluvial origin for the parting. Johnson (1972) suggested that the parting thickens toward the Walshville Channel, a major fluvial deposit in southern Illinois. DeMaris et al. (1983) reported that the parting thickened toward the channel from about 0.1 ft to nearly 2 ft thick. Rare earth elements and clay mineralogy indicate a mineralogical composition that is similar to other shale partings in the coal and to the ash content of the coal (DeMaris et al., 1983; Hughes et al., 1987). Johnson (1979), as part of a petrographic study of the Herrin Coal, interpreted the parting to be the result of a minor transgressive event that temporarily drowned the coal swamp. Clays derived from terrestrial sources were dispersed throughout the coal swamp by gentle wind-driven waves. After a minor regression, coal swamp conditions were re-established.



Shale, calcareous, light gray at top (0.6 ft thick) and base (0.1 ft thick), dark yellowish orange in center, poor to medium fissile, poorly to medium indurated, contains scattered light tan-brown calcareous nodules (0.10–0.15 in diameter).

Limestone, massive, light olive-gray to gray, fossiliferous wackestone; large bioclasts of brachiopods and pelmatozoan columnals common; upper contact sharp and irregular, lower contact sharp and undulating.

Shale, medium gray to light olive-gray, fissile, calcareous, poor to medium induration; lower contact rapidly transitional.

Coal clasts in claystone matrix, thickness variable, coal, black, vitreous, angular; clasts range from pebble size to nearly undisturbed boulder size; claystone, light gray to greenish gray, non-calcareous to weakly calcareous, weakly bedded (color banding) (white top).

Coal, black, vitreous, laminated to thicker bedded; upper portion contains nearly vertical, claystone-filled dikes; upper contact very irregular, lower contact flat and sharp.

Shale, black, non-calcareous, very weakly bedded, poorly indurated.

Coal, black, vitreous, flat and sharp contacts.

Shale, black, non-calcareous, very weakly bedded, poorly indurated.

Coal, black, vitreous, flat and sharp contacts.

Claystone, light brownish gray at base to dark gray at top, massive, non-calcareous, soft (blue band).

Coal, black, vitreous, laminated to thicker bedded; upper contact sharp.

“Underclay” claystone, non-calcareous, weakly bedded (color banding), medium gray to medium dark gray with dark yellowish brown streaks, poor to medium indurated; upper contact sharp and slightly irregular due to deformation (listric deformation planes continue up into lower portion of coal).

Figure 3-6. Stratigraphic column of strata exposed at Stop 2. The formally named units at this exposure are the Herrin Coal and the Brereton Limestone. A boundary between transgressive-regressive units is at the base of the calcareous shale between the coal and the limestone. The Covell Conglomerate is described at Stop 4. See Figure 3-9 for explanation of lithological symbols used on the stratigraphic column. Vertical scale bar equals one foot.



Figure 3-7. View of the white-top deposits in the upper part of the Herrin Coal. The top of the hammer marks the contact between the coal and the overlying calcareous shale and is a boundary between transgressive-regressive units. The rock cropping out a short distance above the hammer is the Brereton Limestone. Note the chaotic pattern of the distribution of the white-top claystone and the coal.



Figure 3-8. View of the middle part of the Herrin Coal bed. The blue band is exposed just above the hammer head.

“White top,” another miner’s term, refers to discontinuous deposits, ranging in lithology from clay to sandy shale to calcareous sandstone, that occur at the top or within the upper part of the Herrin Coal seam (Wanless, 1957). At this site, the deposits consist of very gray claystone (figs. 3-6 and 3-7). The white top appears to thicken at the expense of the coal bed. Wanless (1957) speculated that the deposits were the result of fluvial erosion and deposition during the late stage of the coal swamp environment. This interpretation was based on limited map data suggesting that the distribution of the white top resembled that of fluvial channels. Wanless also noted that the white top occurs where the succeeding Brereton Limestone is present and the Anna Shale is absent. Examination of the white top at this locality indicates that the coal is brecciated, suggesting that deformation occurred after compaction and early dewatering of the accumulation of peat. The association with a vertical dike in the underlying coal, filled with white-top clay, suggests a more complex interpretation, perhaps a combination of late stage dewatering and fluvial processes. Damberger (1970) speculated that earthquake activity that occurred just after deposition of the coal material was associated with the formation of white top.

Road Log Retrace the route back to Maher Road and turn right (north). Turn right (east) onto Parks School Road. Turn right (south) onto Savage Road. At 2.1 mi from the intersection, park along Savage Road between the two yellow triangular no passing zone signs.

Stop 3: Jubilee Lodge

Property Owner State of Illinois.

Location Oak Hill 7.5-minute Quadrangle. SW/4, SE/4, NE/4, Sec. 17, T10N, R6E. Outcrops along southeasterly flowing tributaries to unnamed creek. Sandstone-dominated cutbank (UTM 261055E, 4525915N) will be examined briefly prior to study of the strata shown in figure 3-9 (UTM 261025E, 4525970N).

General Stratigraphy Basal sandstone of cyclothem; eroded clasts of the Herrin Coal; lower Canton Shale.

Description At two small outcrops, we will examine the basal sandstone and the disconformity that Wanless and Weller (1932) used to separate cyclothem. At both outcrops we will examine sandstones that probably correlate to the Copperas Creek Sandstone of the Sparland Cyclothem (Wanless, 1957).

The Copperas Creek at this exposure is a fine- to coarse-grained, dusky yellow to light brown, well-sorted, micaceous, quartz-dominated sandstone. The bedding is variable; it appears massive in some places, but generally is composed of planar beds ranging from very thin to medium in thickness. The lithology at this outcrop is quite similar to the Copperas Creek described by Wanless (1957). According to Wanless, the bed ranges from 3 to 27 ft thick and averages about 10 ft thick. He reported that the sandstone “cut out” the Brereton Limestone and the Anna Shale but not down into the Herrin Coal. In this area, the sandstone likely “cuts out” the Herrin Coal. Based on exposures of the Herrin, mostly to the north and to the west, the extrapolated cropline of the coal bed is within this drainage. Instead of the coal cropping out, however, the outcrops are dominated by sandstone, which is less prominent in the areas where the coal exposures occur. The second exposure visited at this stop offers more evidence for the hypothesis that coal is “cut out” by the sandstone in this drainage.

At the second exposure (figs. 3-9 and 3-10), the lithology of the basal sandstone of the Sparland Cyclothem (Wanless, 1957) is very unusual. The bounding sandstones of cyclothem commonly have conglomerates in the basal portion (Weller, 1930; Wanless, 1957). The lithology exposed here is very unusual in that numerous clasts of coal occur in the conglomerate and two lithologically distinctive conglomerates are present. The basal portion of the channel fill is occupied by a lens of calcareous conglomerate. The silt and sand matrix ranges in lithology from quartz dominated to carbonate dominated. The clasts are variable in both shape and size, and they include clasts of coal and limestone. Bedding is notably absent within this conglomerate. The overlying conglomerate, however, is bedded and is a non-carbonate stratum. The matrix of this conglomerate is a poorly sorted, silty sandstone. Clasts consist of rounded, pebble-sized sideritic (?) nodules and large coal clasts. The coal clasts are lath-shaped in cross section and are slightly rounded at the corners. These coal clasts are remarkable because of their large size, the absence of severe deformation features, and displaying imbricate bedding. The upper conglomeratic layer is overlain by a coarse-grained sandstone, although in places at the outcrop the units are interbedded.

Regression-induced incision by fluvial systems into the underlying strata apparently eroded the previously deposited, semi-lithified limestone deposits and peat of the coal swamp. Water-worn fossil fragments in the basal calcareous conglomerate suggest that the source of the sediments in this stratum was a proximal carbonate deposit. The remarkable preservation of these coal lenses and the occurrence of undisturbed coal in the nearby area suggest that the coal was transported only a short distance. The channel eroded down through the marine strata (Brereton Limestone/Anna Shale), the Herrin Coal, and the "underclay." The thin, dense limestone that occurs just beneath the channel may be equivalent to the limestone in the middle of the Canton Shale of the St. David Cyclothem (see Stop 1). Worthen (1873) had earlier recognized similar unconformities in Peoria County, describing sandstone-filled channels (probably the Vermilionville Sandstone of the Brereton Cyclothem) that had eroded down into and through the Springfield Coal of the St. David Cyclothem.

In the depositional model of a cyclothem (Wanless and Wright, 1978), the basal unconformity of the cyclothem formed as marine waters regressed, allowing widespread erosion and subsequent deposition as clastic material was eroded from terrestrial source areas and transported toward the basin center. The importation of clastic sediments diminished gradually and eventually ceased, allowing the next stage of the depositional cycle to occur (widespread deposition of claystone and mudstone and the formation of the "underclay"). As explained at Stop 1, the separation of the development of the

Figure 3-9. Stratigraphic column of strata exposed at the second outcrop of Stop 3 and explanation of lithological symbols. The boundary of the cyclothem is at the base of the channel. Vertical scale bar equals one foot.

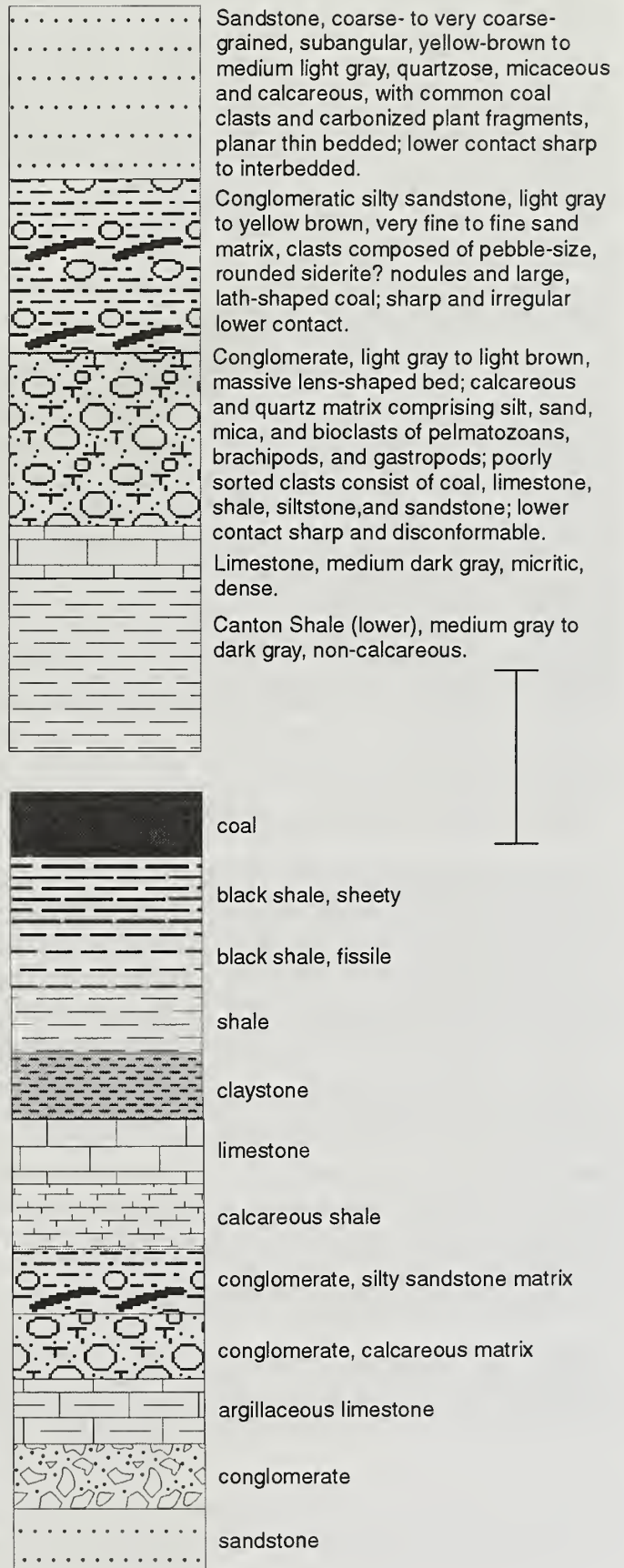




Figure 3-10. View of the strata exposed at the second outcrop of Stop 3. The massive, calcareous conglomerate occupies the base of the channel fill lens and unconformably overlies the thin limestone. The darker lenses within the upper conglomeratic silty sandstone (between the limestone bed and the overlying planar-bedded sandstone) are flattened clasts of coal.

basal unconformity and the “underclay” into two distinct successive events is a significant drawback in the cyclothem depositional model. Disconformity-bounded sandstones deposited in a fluvial regime during a marine regression are unlikely to be basin-wide, whereas the laterally equivalent paleosol disconformity (commonly occurring as the “underclay”) is more likely to be basin-wide. Thus, this disconformity between cyclothems formed as valley incision developed during regression and strand lines of fluvial/deltaic environments prograded seaward.

Wanless (1957) apparently was able to map cyclothems in areas where the basal sandstone units are relatively widespread, and both natural and manmade exposures were abundant at the time of mapping. The usefulness of cyclothems, whether for regional or detailed studies, using both the basal sandstone and the “underclay” disconformities, is restricted in the Illinois Basin primarily because most of the data must come from drilling samples and geophysical logs rather than surface outcrops. Under these conditions, paleosols generally are difficult to recognize, particularly in the absence of thick coal.

Road Log Continue south on Savage Road. Turn left (east) onto Brimfield-Jubilee Road. Turn right (south) onto Princeville-Jubilee Road. Turn right (west) at entrance road to Jubilee College State Historical Site and enter site for ***lunch***.

Return to Princeville-Jubilee Road and turn left (north). Turn right (east) onto Grange Hall Road. Turn right (southwest) onto Voorhees Road. At 0.7 mi from intersection, park along road just before bridge crossing Fargo Run.

Stop 4: Voorhees Bridge

Property Owner Private.

Location Oak Hill 7.5-minute Quadrangle. NW/4, NW/4, SW/4, Sec. 31, T10N, R7E. The composite stratigraphic section (fig. 3-11) is derived from data measured from both upstream (UTM 267840E, 4520460N) and downstream (UTM 267555E, 4520715N) bank exposures. We will examine only exposures upstream from the bridge, mostly in the stream bed near the bridge (UTM 267700E, 4520600N).

General Stratigraphy Houchin Creek Coal, Excello Shale, Covel Conglomerate, and Springfield Coal.

Description The primary stratum to be studied and discussed at this stop is the rather enigmatic Covel Conglomerate. The Covel Conglomerate was named by Willman (1939) for strata exposed along Covel Creek, south of Ottawa, Illinois. The unit occurs at about the same stratigraphic horizon in both northern Illinois and Peoria County. In the Peoria area, the Covel occurs just below the “underclay” unit of the Springfield Coal, and, in the type locality area, occurs beneath the Turner Mine Shale. This black shale generally succeeds the Springfield Coal, but in northern Illinois the coal is absent (Willman and Payne, 1942). The Covel has been described as ranging from a pebble conglomerate to a pebbly coarse-grained sandstone (Willman, 1939; Willman and Payne, 1942). Willman (1939) reported pebbles as large as 0.5 ft in diameter. In the northern Illinois area, the dominant lithology of the clasts is limestone, but calcareous shale and siltstone pebbles are also present. A variety of marine fossils (brachiopods, pelmatozoan columnals, gastropods, pelecypods, bryozoans, trilobites, and conodonts) have been reported to occur mostly within the matrix of the conglomerate. Algal growths have been reported at several localities. For the most part, the Covel Conglomerate in Peoria County appears to have similar characteristics (thickness, clast size range, composition, and sorting). A major difference is that the fossil content of the Covel at this locality is dominated by plants. Marine fossils are relatively rare but include graptolites, although the source of these fossils is unknown. Calcareous laminae of an unknown origin are present and appear to cover the upper surface of some clasts and continue downward into the matrix.

Both Willman and Payne (1942) and Wanless (1957) placed the Covel Conglomerate at the top of the Summun Cyclothem. The placement is somewhat perplexing because the succeeding St. David Cyclothem lacks a basal sandstone, and the Covel resembles, in part, the type of conglomerate that typically occurs in the basal sandstone (e.g., Stop 3). Wanless (1957) reported that a few transported fossil fragments indicate that the bed belongs to the underlying Summun Cyclothem rather than as the basal conglomerate of the St. David Cyclothem. This paleontological correlation should probably be considered suspect because the fossils are water-worn and fragmented, and there is a general lack of supporting data.

Willman and Payne (1942) explained that the conglomerate was formed from previously consolidated pebble material derived from a local source and transported a relatively short distance. A

thin band of laminated limestone was probably deposited by algae over the surface of the bed after the conglomerate was deposited. In a brief study, Hensler and Malone (1998) interpreted the Covell as representing a marine transgressive lag deposit. Examining the conglomerate from the perspective that transgressive-regressive units dominate this stratigraphic column, such a transgression should have been preceded by a regressive event. Strata beneath the Covell, however, record the transgression of marine waters over the Houchin Creek coal swamp along with a probable increase of terrestrial clastic sediment input and less marine influence in the shale immediately under the Covell. The basal contact of the conglomerate appears to be erosional; the surface is generally undulating, the lithologic transition across the contact is a sharp contrast, and the Covell locally cuts down into the underlying strata. It is possible that the Covell records both a regression and a transgression. If so, such events should also be reflected in strata of this interval in other parts of the Illinois Basin, but the corresponding strata have not yet been identified. In addition, the source of the calcareous clasts is unknown; the lithology is not common in the bedrock of this area.

Road Log Continue south on Voorhees Road. Turn right (west) onto US-150. Turn left (south) onto Maher Road. Turn left (east) onto Illinois Highway 8. Turn right (south) onto Eden Road. Turn left (east) onto West Cottonwood Road. At 1.7 mi from the intersection, park along the road.

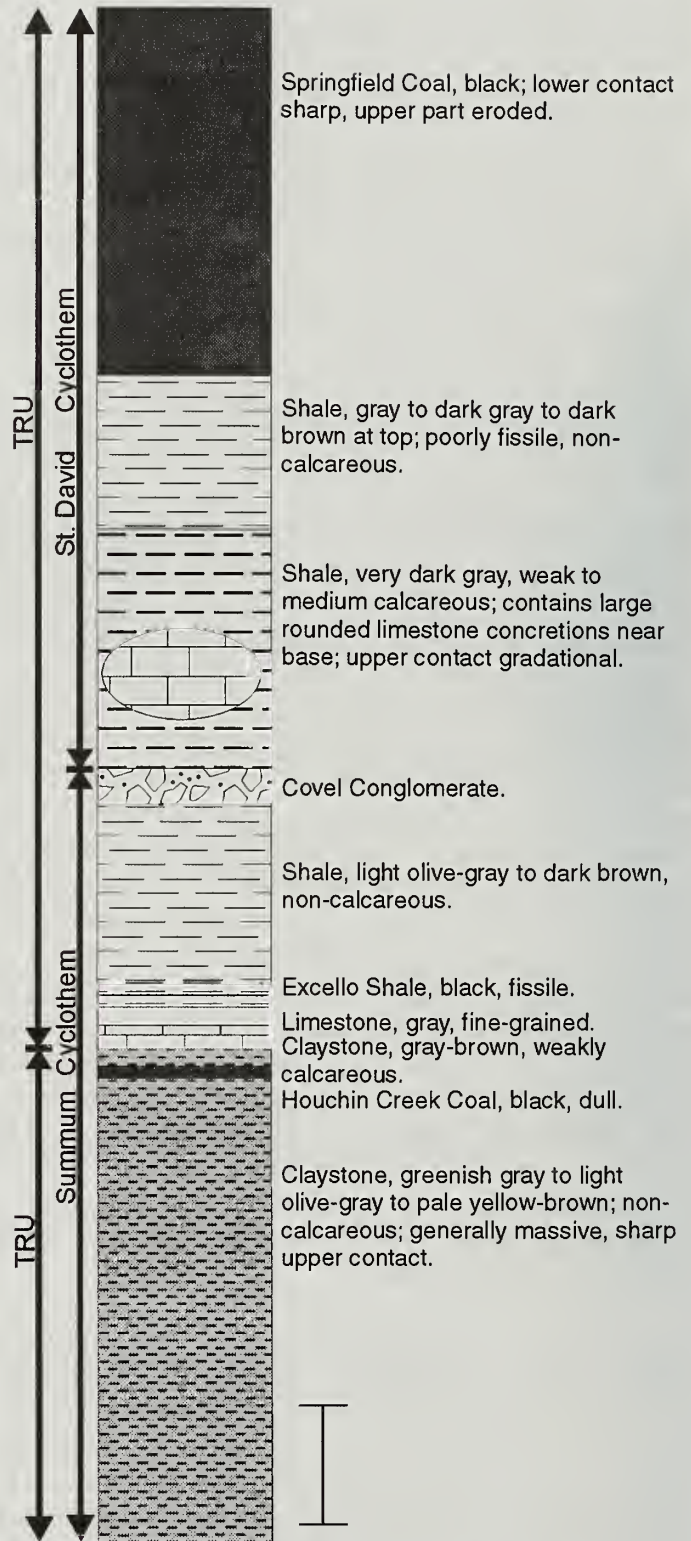


Figure 3-11. Stratigraphic column of strata exposed along Fargo Run at Stop 4. The boundary of the cyclothem is at the base of the channel. TRU, transgressive-regressive unit. The Covell Conglomerate is described in the text for this stop. Lithological symbols used on the stratigraphic column are explained in figure 3-9. Vertical scale bar equals one foot.

Stop 5: Cottonwood Road Strip Pit

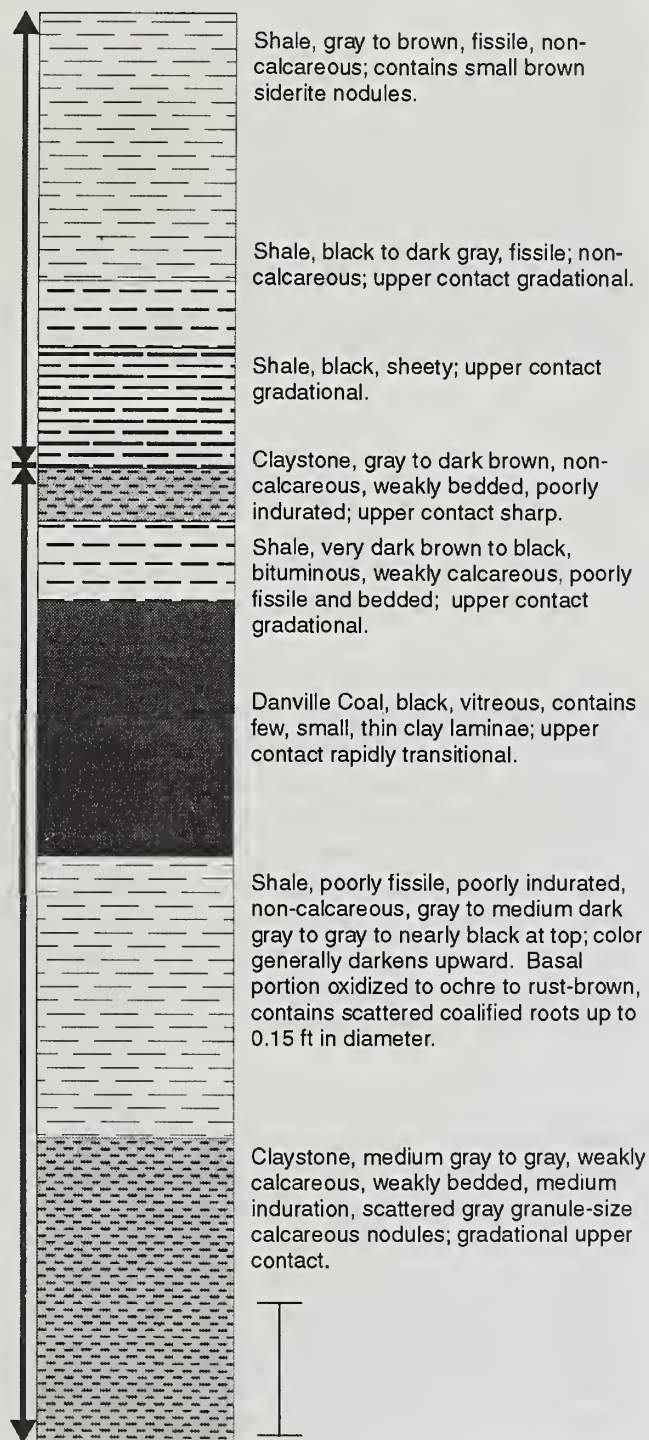
Property Owner City of Peoria. Permission of the lease holders is required to visit this site.

Location Hanna City 7.5-minute Quadrangle. SE/4, SW/4, NE/4, Sec. 27, T9N, R6E. Strata (fig. 3-12) are exposed at the edge of an abandoned strip-mine pit (UTM 261855E, 4512970N).

General Stratigraphy Danville Coal and Farmington Shale.

Description At this outcrop, we will examine the nature of the transition from terrestrial sedimentation to marine sedimentation (from the top of the coal bed to the marine-flooding surface). Weller (1930) had interpreted the succession of marine strata over coal to be caused by a subsidence-driven marine transgression. He considered the marine flooding surface to have merit as a mapping (formational) surface because of its diastrophic (tectonic) origin. Weller, unfortunately, did not describe in detail the characteristics of the terrestrial to marine transition because he selected the basal sandstone unconformity as the mapping boundary. Presumably, he also considered the former transition to record an unconformity. The strata cropping out at this site display an unconformity at the base of the marine strata (figs. 3-12 and 3-13). Here, a thin layer of poorly indurated black to gray fissile shale that succeeds the Danville Coal is overlain, with a small but perceptible angular unconformity, by a black, sheety shale that records the marine transgression. Marine fossils have not been found in the

Figure 3-12. Stratigraphic column of strata exposed at Stop 5. The boundary between transgressive-regressive units is at the base of the black sheety shale, as indicated by the arrows. The dark shale and claystone units succeeding the Danville Coal form a small lens-shaped deposit that is unconformably succeeded by the black shale. The base of the latter shale represents the initial marine transgression over the largely terrestrial underlying deposits. Lithological symbols used on the stratigraphic column are explained in figure 3-9. Vertical scale bar equals one foot.



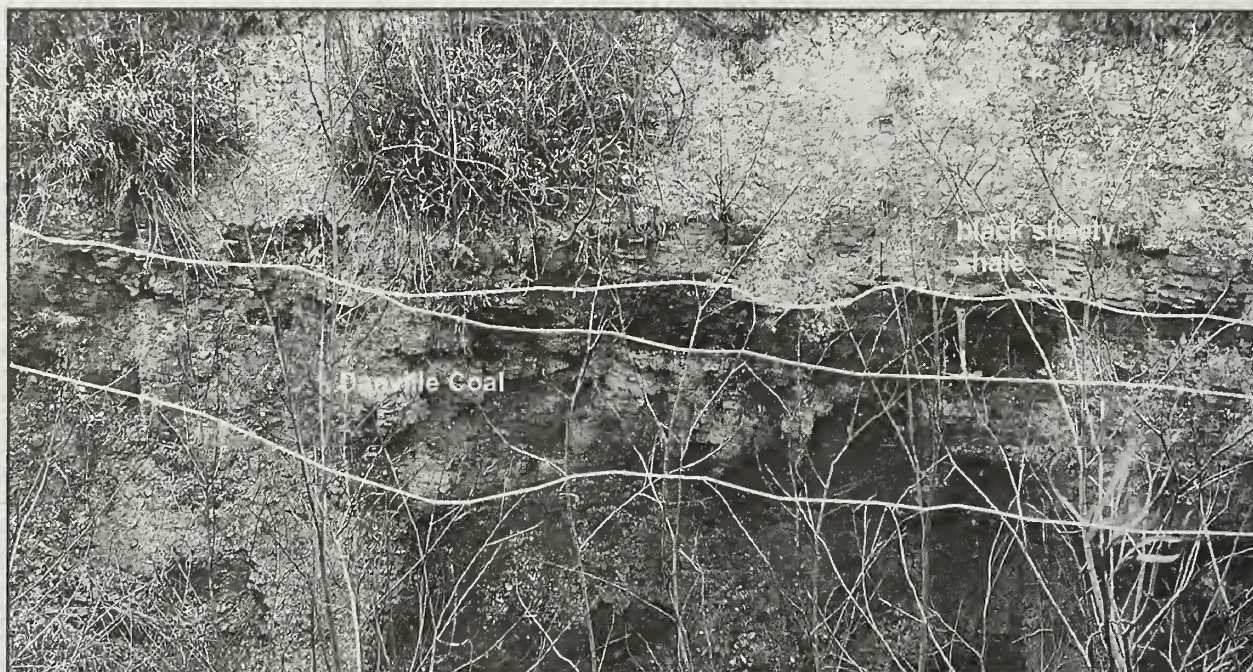


Figure 3-13. View of the strata exposed at Stop 5. The dark shale and claystone units constitute the lens-shaped deposit between the Danville Coal below and the black sheeted shale above. The hammer lies on the lens-shaped bed. Bedding planes within this lens form an angular unconformity with beds of the overlying black shale, which are particularly well displayed near the left end of the lens.

black to gray shale; it probably represents a depositional environment of fresh to brackish water that flooded the coal swamp prior to invasion of marine water.

A few other studies have reported unconformable relationships between coal beds and the marine-flooding strata. DeMaris and Nelson (1990) suggested that a relatively short hiatus had occurred at the contact between the Herrin Coal Member and the overlying marine strata in the Carbondale Formation in southwestern Illinois. During a transgression, sediments commonly are reworked at the water-substrate surface, leaving a transgressional lag over a ravinement surface at the base of marine strata. Transgressional lags have been described by Zangerl and Richardson (1963), Palmer et al. (1979), Weibel (1988, 1991), and Weibel et al. (1989). Transgressive lags are less widespread in calcareous strata, but Scheihing and Langenheim (1985) described abraded fragments of marine fossils in a basal marine stratum of the Shumway cyclothem. Near certain large channels, DeMaris et al. (1983) found that the coal was overlain by nonmarine to marginal marine shale, the top of which has been subjected to submarine erosion, followed by deposition of marine shale.

Road Log Continue east on West Cottonwood Road. Turn left (north) onto Murphy Road. Turn right (east) on IL-8. Turn left (north) onto Kickapoo-Edwards Road. Cross over I-74 and turn left and park at Jubilee Café. **Coffee break.**

Leave the café parking lot and turn left (north). Enter Kickapoo village; turn right (east) onto US-150. Just east of Kickapoo, the route gradually ascends the outwash plain proximal to the Buda Moraine, part of the Bloomington Morainic system. Cross over IL-6 and enter Peoria City limits. Turn right (south) onto Big Hollow Road. At 1.2 mi from IL-6, park on the abandoned road pavement on the left (east) side of road, just north of the bridge over Big Hollow Creek.

Stop 6: Big Hollow Creek

Property Owners City of Peoria and private.

Location Dunlap 7.5-minute Quadrangle. SW/4, NW/4, SE/4, Sec. 13, T9N, R7E. Strata (fig. 3-14) are exposed in a cutbank on the west side of Big Hollow creek (UTM 276415E, 4515105N).

General Stratigraphy Springfield Coal, Turner Mine Shale, and Canton Shale.

Description This outcrop displays, from the base upward, an overall succession of depositional environments from terrestrial to marine. The exposure is similar to the other outcrops of the interval examined at previous stops, except that it contains an anomalous sequence between the Springfield Coal and the Turner Mine Shale (fig. 3-14). The argillaceous limestone-black shale-gray claystone interval (fig. 3-15) succeeding the coal was not reported by Wanless (1957) in his study of four 15-minute quadrangles just to the southwest. In that study area, the coal is overlain by the black Turner Mine Shale. Wanless did report a single occurrence of alternating laminae of coal and marine fossils at the top of the coal near Cuba in Fulton County, but those strata probably are the local record of the initial marine transgression. Another possibility is that those strata could extend laterally in the subsurface for some distance to the southeast.

The three-bed interval at this site, which pinches out at the upstream end of the exposure (fig. 3-15),

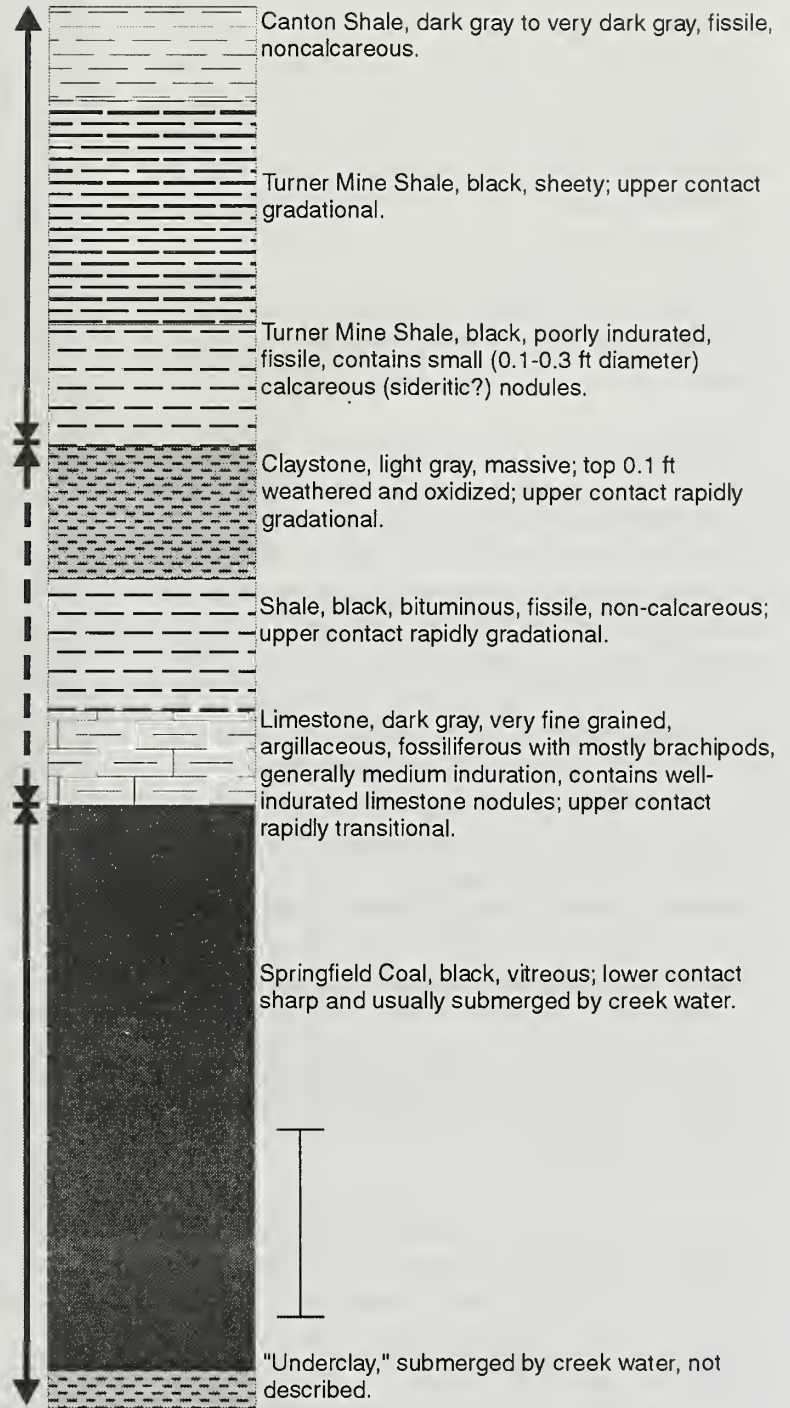


Figure 3-14. Stratigraphic column of strata exposed at Stop 6. At this exposure, there is a minor transgressive-regressive unit (dashed arrow line at left), which occurs between the Springfield Coal and the Turner Mine Shale. These beds pinch out at the upstream end of the outcrop where the Turner Mine Shale directly overlies the coal. Lithological symbols used on the stratigraphic column are explained in figure 3-9. Vertical scale bar equals one foot.

indicates that marine waters transgressed over the coal swamp, depositing initially the argillaceous limestone followed by the overlying black shale. Bituminous layers within this black shale (deposition of terrestrial plant material) and the succeeding massive claystone indicate that a shallowing event occurred (minor regression). Marine fossils have not been observed in the claystone, suggesting that it was deposited in either a non-marine or, at least, a marginal marine environment. Evidence for terrestrial deposition has yet to be recognized.

For the most part, I have regarded Pennsylvanian marine transgressions as large, significant events that rapidly overwhelmed the pre-existing depositional environments, which was, in many cases, the coal swamp environment. This viewpoint is undoubtedly simplistic, although Heckel (1996) also advocated rapid, widespread marine transgressions for Pennsylvanian cyclothems. The strata exposed may be the record of a step-wise transgression marked by the initial transgression depositing the limestone; a minor regression recorded by the black, bituminous shale and claystone; followed by a second, more extensive marine transgression that deposited the Turner Mine Shale (fig. 3-14). The pinching out of this three-bed interval and the lack of reported occurrences of this interval at other exposures of either the Springfield Coal or the Turner Mine Shale suggest that the factors controlling its deposition are of local rather than of basin-wide extent.

This last field trip stop offers an excellent opportunity to review and summarize the stratigraphic concepts that have been presented. The depositional model of Wanless and Weller's (1932) cyclothem can be revised and improved by recognizing that, during the regressive phase (retreat of marine water), fluvial erosion of the newly exposed land surface and the initiation of soil-forming processes occurred simultaneously. The traditional basal sandstone disconformity of the cyclothem, thus, is chronologically equivalent to the "underclay" paleosol that commonly occurs beneath coal beds (basal unit; figs. 3-14 and 3-15). This revision of the cyclothem model, however, still does not make the cyclothem an appropriate stratigraphic mapping unit because of the difficulty in identifying its boundaries from subsurface data. An informal unit, the transgressive-regressive unit, a lithological succession bounded by marine transgressive surfaces, is a more practical mapping unit for cyclothem strata in the Illinois Basin because the marine lithologies are more readily recognized in well samples and geophysical logs. In addition, marine beds are



Figure 3-15. View of the strata exposed at Stop 6. The "underclay" crops out at the level of the dry creek bed. The hammer head rests upon the contact between the Springfield Coal and the argillaceous limestone. The contact between the bituminous black shale and the succeeding claystone is just above the hammer handle. In most places, the Turner Mine Shale, which overlies the claystone, generally marks the initial marine transgression within this succession. At this site, however, a minor transgressive-regressive event occurred, depositing the three beds, which pinch out to the right, between the coal and the Turner Mine Shale.

present in most, if not all, of the Pennsylvanian cyclothemic strata. Coal beds are readily mappable as key beds only in the Middle Pennsylvanian; they are either absent or very thin in most other parts of the Pennsylvanian System. Mapping of the transgressive-regressive units may lead to a better understanding of the sedimentary history of the basin because these units and the related cyclothems are both based on the alternating transgressive and regressive character of the strata. Because of this alternation, the disconformable surface and the marine transgressive surface also occur in an alternating pattern in the stratigraphic column.

Road Log Continue southeast on Big Hollow Road. Turn left (north) onto Glen Hollow Road. Turn right (southeast) onto War Memorial Drive (US-150). Turn right onto entrance ramp to I-74 east. Continue on I-74 east to Bloomington-Normal. End of log.

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Geology of the Vermilion River Gorge, La Salle County, Illinois

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INTRODUCTION

The lower Vermilion River near Oglesby, Illinois, has carved a spectacular gorge near its confluence with the Illinois River. In places, the stream lies nearly 200 ft below the till plains of La Salle County; at several localities, steep bedrock exposures are as high as 100 ft. Abundant exposures of bedrock in the streambed (in some cases producing significant rapids), a steep gradient (7.5ft/mile in the section described here), and a nearly V-shaped valley profile suggest that this stream is still actively downcutting. The local base level was significantly lowered by the downcutting of the Illinois River valley during the drainage of late Pleistocene proglacial lakes, and the Vermilion River has yet to achieve a graded profile.

The dynamic geomorphic processes in the Vermilion River gorge make it an outstanding place to investigate fluvial geomorphology. Furthermore, this river has carved its canyon through some of the most interesting and economically valuable bedrock strata in the state, which makes this area an ideal site to study several other aspects of Illinois geology as well. The excellent exposures of Pennsylvanian strata (the Carbondale Formation, in particular) are some of the most complete natural exposures of these units anywhere. The Ordovician Galena-Platteville Dolomite and St. Peter Sandstone also outcrop in or near the stream valley, and there are several exposures of the Pennsylvanian/Ordovician unconformity. Structurally, the area is of interest as it lies along the Peru Monocline, the steeply dipping southwestern limb of the La Salle anticlinorium (Nelson, 1995).

Three locations in the gorge are traditional favorites for field trip stops: (1) the mouth of Dells Creek in Matthiesson State Park, where beds of Galena-Platteville Dolomite dip at angles of nearly 30° into the bed of the Vermilion River (Nelson and Malone, 1997); (2) the high cut bank located in the Margery C. Carlson Nature Preserve, on the southwestern side of the river approximately 0.5 mi (0.8 km) downstream from the Illinois Highway 178 bridge, where bluffs of up to 45 m in height expose portions of several cyclothems in the Carbondale Formation (Trask, 1987); and (3) the canoe/kayak launch site at the Lowell Bridge on IL 178, where a patchy channel fill deposit of sandstone and shale above the Galena-Platteville Dolomite marks the Pennsylvanian/Ordovician unconformity (Nelson et al., 1996).

At the first two localities, the physical challenges of reaching the interesting geology have sometimes caused problems for field trip planners. At Matthiesson State Park, the river location can be reached after a 0.8-km hike on a well-maintained trail, followed by 100 m or so of scrambling down the steep slope to the river. At the Carlson Preserve site, the trail is a little longer and less

manicured, and the steep banks leading down to the river make extensive exploration of the exposure difficult and dangerous.

Viewing these sites from the river has the advantage of allowing the viewer to go directly to the base of these spectacular exposures in relative comfort. However, the Vermilion is generally regarded as one of the most challenging whitewater streams in the state, and the trip is definitely not recommended for novice canoeists. Rafts are much more forgiving of paddler errors and should safely carry trip participants through the gorge. However, two sites—Wildcat Rapids and the dam at the Lone Star cement plant—require particular care. On the day of the field trip, after assessing water levels and other factors, trip leaders will advise the group as to the best way to negotiate these areas.

This field guide is for a one-day rafting trip down the Vermilion River. It is geared mainly toward K–16 geoscience educators. The mileage and locations of the sites discussed in this field guide are shown in figure 4-1. “Right” and “left” bank designations are from a downstream-looking vantage point.

RIVER LOG AND SITE DESCRIPTIONS

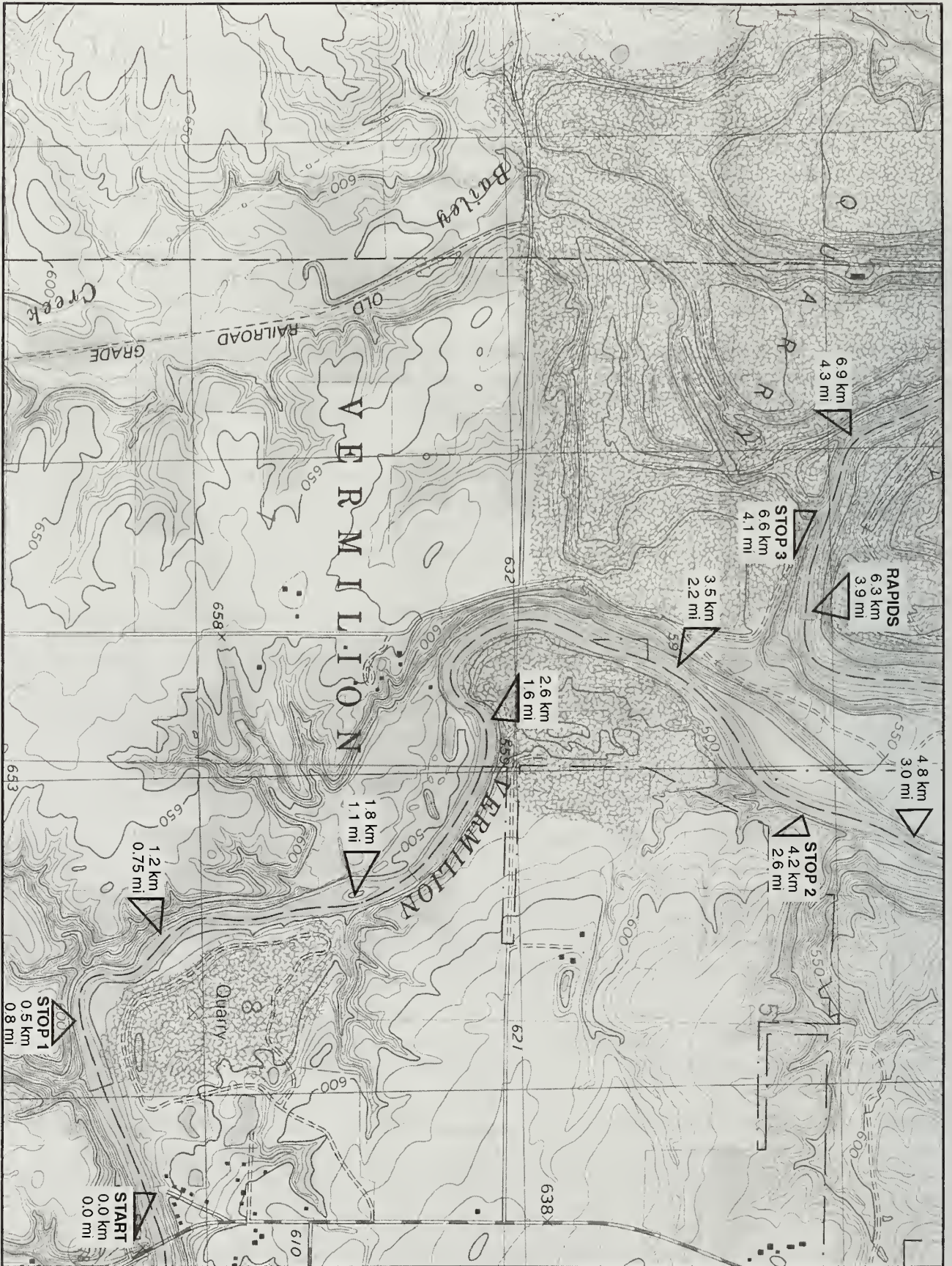
Mile 0 (Kilometer 0)

Begin the trip at the stream bank outcrop of the Galena-Platteville Dolomite just downstream of the north abutment of the IL 178 bridge over the Vermilion River. This site is a favorite put-in site for rafters on the river. The shallow rocky rapids that extend from above the bridge to the first bend downstream from the put-in is known as the Lowell Bridge Rapids. The river is flowing over bedrock here, and in low water the exposure of rock in the riverbed is quite spectacular. The beds of dolomite here dip to the southwest at 5–10°, so a downstream traveler gradually moves up-section. At the first bend (Mile 0.5), the angle of dip increases dramatically as the Galena-Platteville strata submerge beneath the riverbed at the Pennsylvanian/Ordovician unconformity.

At the put-in locality, Pennsylvanian sandstone and shale can be seen unconformably overlying the Ordovician rocks. This deposit has been described as a channel deposit (Nelson et al., 1996), but the apparent steepness of the “paleochannel” walls and the location near the axis of the La Salle anticline have also led to an interpretation of this deposit as a structural feature. It may be a small-scale graben or a filled paleokarst feature that formed as solution activity widened a pre-Pennsylvanian fracture (Stephen Marshak, University of Illinois, personal communication).

Mile 0.5 (Kilometer 0.8)

Stop 1: Lowell Bluff Section Floating downstream from the put-in, notice the gentle westward dip of the well-exposed Galena-Platteville Dolomite at the base of the old bridge abutments on the right. In low water, this stretch can be an intricate, shallow maze with a few navigable channels through breaks in the dolomite ledges. In high water, this stretch is a fairly continuous choppy rapids, and a landing on the left bank can be tricky. A few eddies are usually formed by rocky projections along the bank, and a safe landing can be made in one of these eddies.



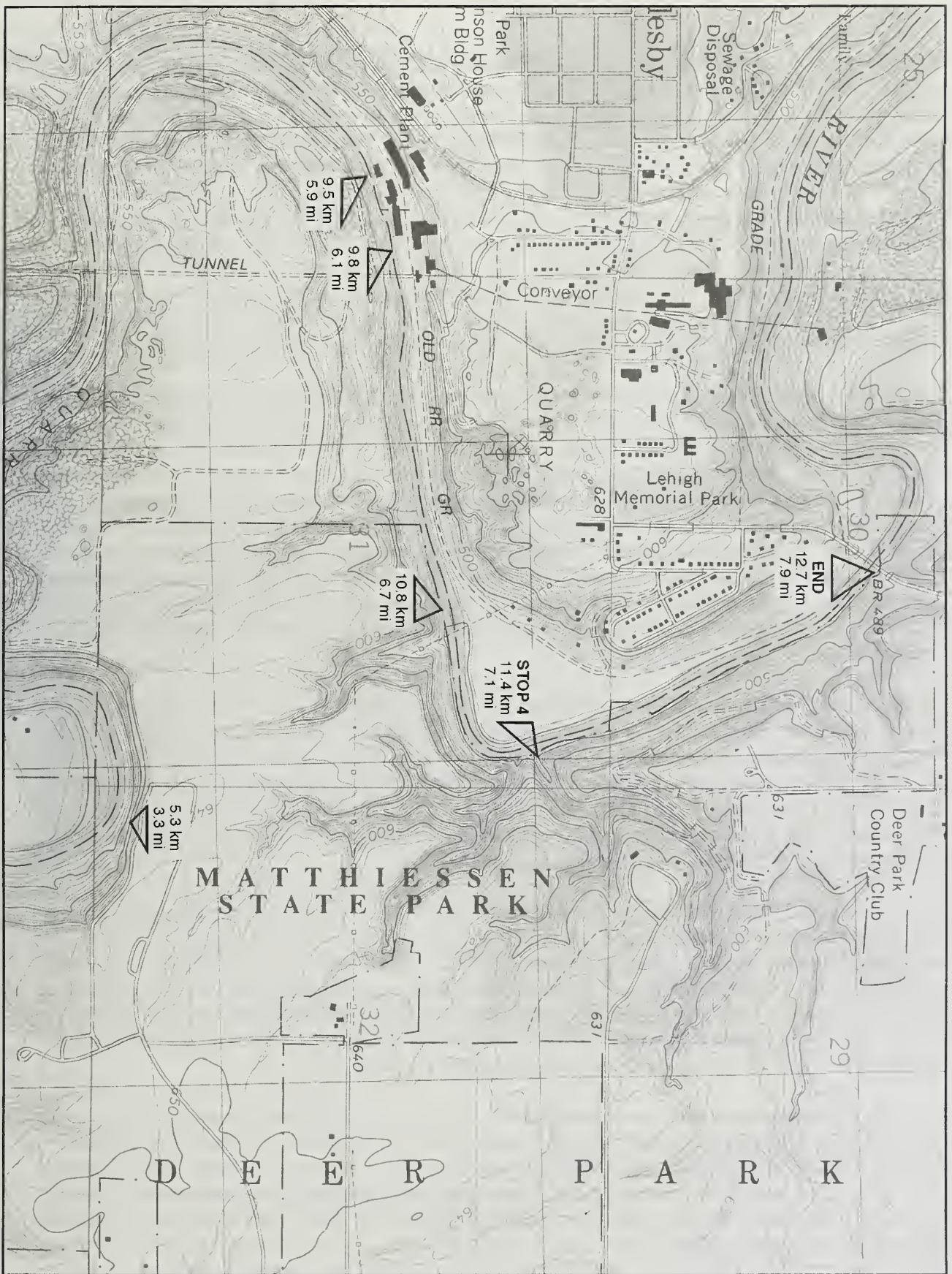


Figure 4-1. Map of the Vermilion River gorge showing field trip localities and mileage.

The high bluff along the south and west banks here was described by Cady (1919), Smith et al. (1970), and Trask (1987) in the Geological Society of America Centennial Field Guide Series (fig.4-2). The lower portion of the section (Tonica Cyclothem) is well exposed and easily accessible here, and the continued erosion of this cutbank by the river ensures that fresh exposures will always be available for study. If not covered by slump material, the Colchester Coal can usually be seen here just a few feet above the river. The coal is about 1 m thick here, and the shale just above the coal contains abundant pyrite nodules. Approximately 3 m of Francis Creek Shale separate the Colchester from one of the most distinctive units in the area, the Mecca Quarry Shale. The Colchester, Francis Creek Shale, and Mecca Quarry Shale can be seen at numerous locations along the next 2–3 mi (3.2–4.6 km) of riverbank, and they provide convenient stratigraphic markers. The Mecca Quarry is a very resistant, slaty, fissile “paper shale.” This is a prominent ledge former that can generally be tentatively identified even in distant exposures.

The Francis Creek Shale is a unit well-known worldwide as the source of one of the best “Lagerstätten” fossil assemblages in the world. Farther east, in the Mazon Creek drainage basin, abundant siderite concretions have been collected by generations of paleontologists as well as amateur fossil collectors. As huge quantities of the shale were stripped away to provide access to the underlying Colchester Coal during the middle decades of the twentieth century, diverse assemblages of both terrestrial plant and animal fossils (the “Braidwood flora”) as well as marine animals (the “Essex fauna”) were described from the shale, and much of our knowledge of Pennsylvanian life comes from this member. However, the unique set of depositional and diagenetic factors that led to the preservation of the Mazon Creek Biota do not appear to have prevailed in this area, and although siderite concretions do occur along the Vermilion river, they rarely contain fossils.

Overlying the Francis Creek Shale, the Mecca Quarry is considered to be the “core shale” of the Tonica Cyclothem, representing anoxic deposition in deep waters at the maximum transgression. The thick shale overlying the Mecca Quarry is called the Oak Grove Limestone Member by Smith et al. (1970), although limestone is a minor part of the unit. It is found as discontinuous layers of flattened pods and septarian nodules within the dominant dark gray sandy shale lithology. The Oak Grove is the regressive phase of the cyclothem and is topped by an unconformity and the thin Lowell coal at the base of the Lowell Cyclothem.

Units above the Tonica and Lowell Cyclothems are also well exposed here, but access is difficult and dangerous on the steep slopes. Most of the higher units can be examined more conveniently at other sites further downstream (particularly at Stop 2, Mile 2.6), and “binocular geology” is generally the most prudent way to examine these units here. Approaching the west end of the outcrop, where the river rounds a bend to the right, a trickling waterfall spills over a resistant bed at the base of the Lowell Cyclothem. Sharp eyes (or less-sharp eyes aided by binoculars) can sometimes locate the Lowell Coal in the creek bed near the lip of the falls.

Immediately downstream from the waterfall bend, a large area of slumped material is encountered on the left bank. In early spring or late fall, when foliage is not present, the scarp can be seen clearly from this vantage point in the light tan Vermilionville Sandstone and loess that tops the bluff. The toe of the slump has forced the river to bend sharply to the east, and several large boulders of sandstone line the left bank at this point. This slump is not evident on the topographic base map (surveyed in 1909) used by Cady in his 1919 geologic map of the area (Cady, 1919), which shows a straight stretch of river flowing past a very steep, east-facing escarpment (fig. 4-3). However, the topographic map prepared in 1966 shows a much more gentle slope in the area

Description of strata exposed at Stop 1

1. Sandstone, brownish gray, thin bedded; interbedded with sandy shale; contains many black carbonaceous partings.
2. Sandstone, brown, fine-grained, poorly sorted, occurring in one massive bed.
3. Shale, gray, lower part fossiliferous (gastropods); contains layers of discoid, septarian, fossiliferous ironstone concretions; grades into underlying shale.
4. Shale, black, well-bedded, hard, slaty; contains thin phosphatic lenses and laminae, especially in lower part; occasional gray limestone nodules up to 2.5 cm thick; contains *Avicoupeten* in lower part.
5. Shale, black, very calcitic and fossiliferous; *Marginifera* and crinoid debris; pyritic.
6. Conglomerate, composed of poorly sorted, fine-grained limestone particles (up to 12 mm) in a pyritic matrix; fossiliferous.
7. Claystone, medium dark gray, becoming lighter in color downward with some mottling; reddish in lower 25 cm; contains irregular calcite masses up to 2.5 cm thick in bottom 50 cm; calcite throughout.
8. Shale, light gray, fossiliferous, as below; contains several lenticular limestone units up to 7.6 cm thick.
9. Limestone, light greenish gray, impure; nodular in lower part; fossiliferous with abundant productids and crinoid stems.
10. Shale, medium gray, slightly green.
11. Shale, medium dark gray, mottled with greenish gray; interbedded with medium gray, thinly laminated siltstone beds up to 7.6 cm thick.
12. Shale, black, smooth, well laminated, relatively soft, coaly in parts.
13. Claystone, medium olive-gray; relatively firm and calcitic, especially in lower 1.2 m; a few small slickensided surfaces.
14. Claystone, light greenish gray, yellow cast; silty, noncalcareous; contains sandy limestone nodules up to 5.5 cm thick in the lower 20 cm.
15. Limestone, light greenish gray, sandy, clayey, massive.
16. Sandstone, light greenish gray, fine-grained, calcitic, clayey, thin bedded.
17. Shale, light greenish gray, fine, micaceous, sandy near top; contains small nodules of sandy gray limestone which weather rusty; contains a 20-cm mottled, soft, red and green shale 0.3 m from base; interval mostly covered.
18. Limestone, light gray, weathers reddish in part, septarian; fossiliferous; *Marginifera* (abundant), *Mesolobus*, *Ambocoelia*; forms a consistent nodular bed.
19. Shale, medium gray, weathers tan, soft, slightly fossiliferous; contains several siderite nodules in lower part; contains an 18-cm zone of light olive-gray, lithographic septarian limestone nodules 0.7 m from base; basal 35 cm poorly bedded.
20. Shale, dark gray; fossiliferous; *Mesolobus*, *Marginifera*, *Neospirifer*.
21. Coal, contains several dull shaly bands.
22. Siltstones, medium dark gray, sandy, calcitic, micaceous; contains vertical plant impressions and charcoal streaks.
23. Shale, dark gray, sandy, micaceous, generally thick bedded; contains two prominent zones of lenticular, semi-lithographic septarian limestones up to 0.5 m thick and containing a few fossils; several thinner and less persistent nodular limestone zones also present; a few crinoid stem fragments noted near base.
24. Shale, black, hard, slaty; contains large discoidal concretions of dark gray limestone up to 15 cm thick, mostly in lower 0.3 m.
25. Shale, light gray, soft, thin bedded; contains a few sideritic concretions; generally not exposed.
26. Coal, has been mined out locally.
27. Claystone, gray, noncalcareous; where thicker than 2 m, commonly consists of three beds; lower gray claystone, thin discontinuous green claystone or shale, and upper gray claystone.
28. Dolostone.

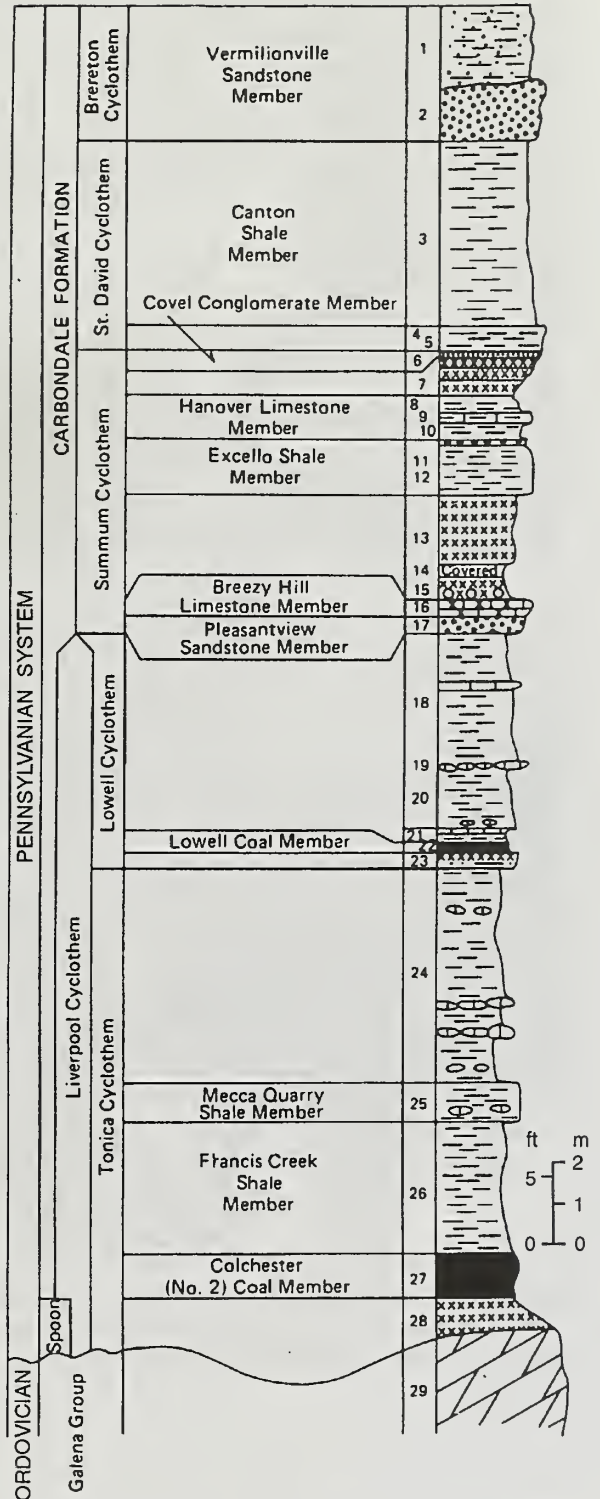


Figure 4-2. Stratigraphic column of the Lowell site (after Smith et al., 1970).

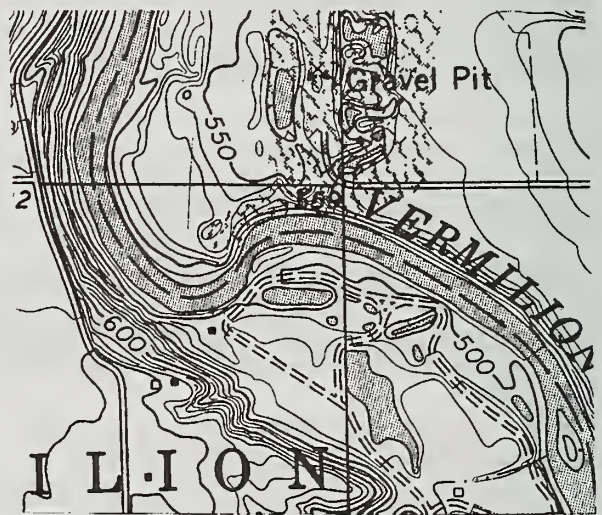
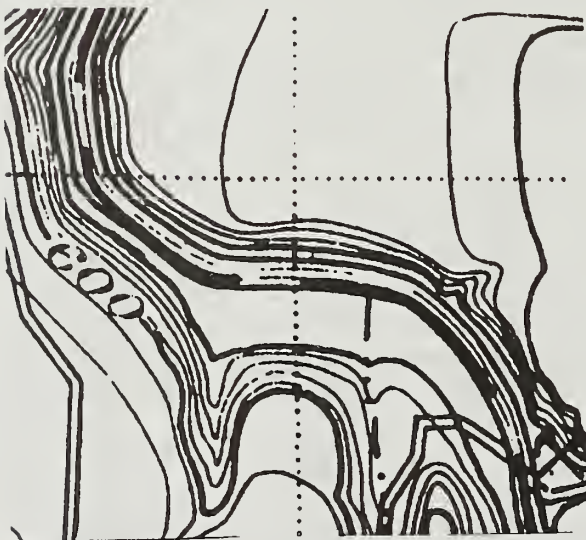
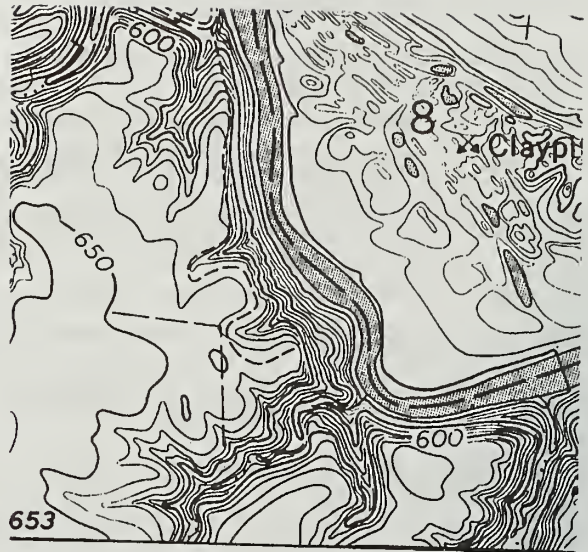
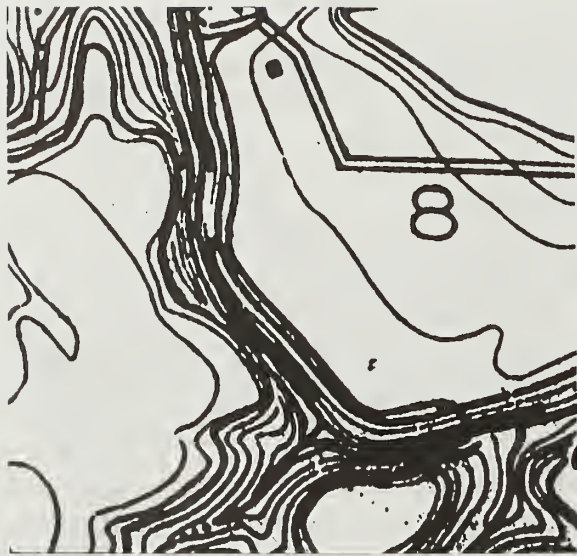


Figure 4-3. Topographic maps showing the apparent changes in the river course between the 1909 and 1965 surveys. The 1909 survey (1:62,500) is shown on the left; the 1965 survey (1:24,000) is on the right. Both maps are magnified to approximately the same scale. Top, area around Mile 0.5; bottom, bend at Mile 1.6.

and a sharp bend in the river as the channel was displaced eastward by the slide. Because of the low competence of the shales that dominate the north-facing slope at this site, it seems likely that a similar slide could occur on this slope in the coming decades as the river continues to oversteepen the bank.

Mile 0.75 (Kilometer 1.2)

As the river bends west again after rounding the slump block, a spectacular bluff comes into view on the left. From a distance, many of the units from the Lowell stratigraphic section (discussed at Stop 1) are visible (fig. 4-4), from the Vermilionville Sandstone and Canton Shale at the top to the familiar Colchester Coal, Francis Creek Shale, Mecca Quarry Shale triad at the base. The Colchester Coal is well exposed here, and in low water conditions its underclay can be examined (fig. 4-5). The unconformable contact with the Galena-Platteville Formation is in the riverbed here, and some low outcrops of the Galena-Platteville are visible along the east bank. The Moline Consumers Company Vermilion Quarry lies a short distance beyond the east bank.



Figure 4-4. Photograph of the river bluff at Mile 0.75. Note the light-colored Vermilionville Sandstone at the top and Mecca Quarry Shale about one-fourth of the way up the slope from the river.

Near the downstream end of this exposure is a large block of Mecca Quarry shale that is dominated by a cluster of large (0.5 m or larger) limestone nodules. These nodules appear light tan on weathered surfaces, but fresh surfaces are black.

Mile 1.1 (Kilometer 1.8)

A small island divides the river here, with riffles in both channels. At the entrance to the west channel, the Francis Creek and Mecca Quarry Shales are exposed in a cut bank; the east channel flows over a knobby outcrop of Galena-Platteville Dolomite. This outcrop forces an abrupt bend in the stream, and, in extremely low water conditions, some water flows through small caverns in the outcrop. The upper 20 to 50 cm of rock is much more resistant than the underlying material, and much of this softer material has been dissolved or abraded away to form



Figure 4-5. Photograph of rafters observing Colchester Coal at Mile 0.75.

low passageways under the surface crust. The surface of this outcrop is very hummocky and irregular and resembles the exhumed Pennsylvanian erosion surface exposed in the Starved Rock Clay Products Quarry located approximately 4 mi (6.4 km) to the northeast.

Mile 1.6 (Kilometer 2.6)

The river has deeply undercut the Vermilionville Sandstone at this point as the channel bends abruptly to the east (fig. 4-6). Exercise caution at this point during high water, as the current tends to rapidly sweep a raft under the low overhang. Trough cross-bedding is nicely exposed in this dramatic cliff outcrop, and the basal contact between the Vermilionville and the underlying Canton Shale can be followed up the slope to the east.

Approaching this site, the Vermilionville can be seen through a thin screen of trees along the right (east) bank. The river is flowing through the most steeply dipping portion of the southwestern limb of the La Salle Anticline at this point, and, as the river bends to the west, the sandstone drops rapidly in elevation. The contact between the Vermilionville and the Canton dips beneath the river near the beginning of the steep bluff, but in low water some interesting loading structures can be seen here. The thickness of the sandstone at this site (approximately 10 m) and the abundant trough cross-bedding suggest that it is a channel deposit.

This site reveals a substantial change in the river morphology since the 1909 topographic map. The earlier map shows a very gentle curve to the west, but the 1965 map shows a much more pronounced S-curve (fig. 4-3). This curve has become more pronounced as the soft shale on



Figure 4-6. Photograph of undercut Vermilionville Sandstone at Mile 1.6.

the east has been cut back while the harder sandstone has proved to be more resistant. Where the shale lies vertically beneath the sandstone, undercutting has been extreme.

Mile 2.2 (Kilometer 3.5)

A coal seam can be seen along the left bank at this locality. The coal is about 1.4 m thick, and there is a gray limestone unit 1 m beneath the base. These are probably the Danville (No. 7) Coal and the Brereton Limestone of the Shelburn Formation.

Up until Mile 2, the river has been flowing basically west or northwest and up-section. After that point, the river bends to the north and then northeast, back down-section. This site is a few meters above the Vermilionville Sandstone. In low water, some outcrops of the sandstone can usually be seen along the banks or in the streambed a short distance downstream from the site.

Mile 2.6 (Kilometer 4.2)

A prominent syncline can be seen in the bluff along the right bank here in a ledge of black slatey shale (fig. 4-7). As usual, the most interesting geology tends to be located at some of the worst landing sites. The best areas are usually located between the axis of the fold and the bed of gray sandstone that angles up from the northern limb, although at some water levels rafts can be landed at the upstream limb of the fold. A stratigraphic column of this section is provided as figure 4-8.

Stop 2: Syncline in Steep Cutbank near the Southern Boundary of Matthiesson State Park Two small tributaries join the river here, one just above the site and one below. Between the two stream mouths, a prominent bluff displays a spectacular syncline. The axis



Figure 4-7. Photograph of syncline at Stop 2 (Mile 2.6). Prominent ledge is a resistant “slatey” shale near the base of Canton Shale.

of the syncline trends roughly east-west, and the limbs dip at angles of up to 15° . Units exposed at this locality are shown in figure 4-8. The Pleasantview Sandstone forms a ledge that angles up from the river near the north end of the outcrop. The overlying Excello Shale contains abundant large crinoid columnal sections in a zone just below the top of the unit. The Hanover Shale contains crinoid debris as well, and the upper surface of the limestone is in many places covered with a layer of brachiopods. Above the Hanover, the thin but distinctive Covell Conglomerate can be found, consisting of rounded black phosphatic pellets surrounded by pyrite. The prominent black shale that defines the syncline lies just above the Covell; the remainder of the outcrop consists of gray to brown Canton Shale.

This area provides excellent opportunities to investigate lithologic units that were visible but inaccessible at site 2. In addition to the river bluff syncline, these units can be viewed in either of the creekbeds that lead into the uplands north and south of the bluff. The northernmost creek has cut through the Pennsylvanian and has carved a narrow gorge into the underlying Galena-Platteville Dolomite. Walking up through the creekbed, exposures of Mecca Quarry Shale and Colchester Coal can be observed near the Ordovician unconformity. Many small-scale folds are evident in these exposures. The land along the right bank in this area is within the boundaries of Matthiesson State Park.

Description of strata exposed at Stop 2 Top of section

1. 4.0 m **Canton Shale:** Shale, soft, gray to tan; weathered pyrite nodules.
2. 0.7 m Calcareous gray shale with discontinuous strata of flattened micrite nodules.
3. 0.7 m Black shale, relatively soft.
4. 0.35 m Black shale, very hard, "slaty," and fissile; prominent ledge former.
5. 0.2 m Soft gray shale.
6. 1.0–3.0 cm **Covel Creek Conglomerate:** Conglomerate, rounded limestone and phosphate particles in pyrite matrix.
7. 0.6 m Soft gray shale.
8. 0.5 m **Hanover Limestone:** Massive limestone with productid brachiopods and crinoid columnals. Top of unit is shell lag deposit of productids.
9. 0.5 m Brown shale. Lower is very soft; upper 0.2 m is much harder. Lag deposit of large (diameters up to 17 mm) crinoid columnals at top. Articulated segments 2–5 cm are common.
10. 1.5 m **Excello Shale:** Silty shale, very hard, mm scale black and gray laminations.
11. 3.0 m Covered.
12. 1.0 m Shale, lower is gray; upper grades to nearly black.
13. 0.0–0.4 m **Breezy Hill Limestone:** Discontinuous nodular limestone, gray, argillaceous.
14. 0.4 m Gray shale, very silty.
15. 1.1 m **Pleasantview Sandstone:** Argillaceous, micaceous, thin-bedded and fissile. Gray to light tan. Upper surface has prominent, nodular limonite-stained corrosion surface.

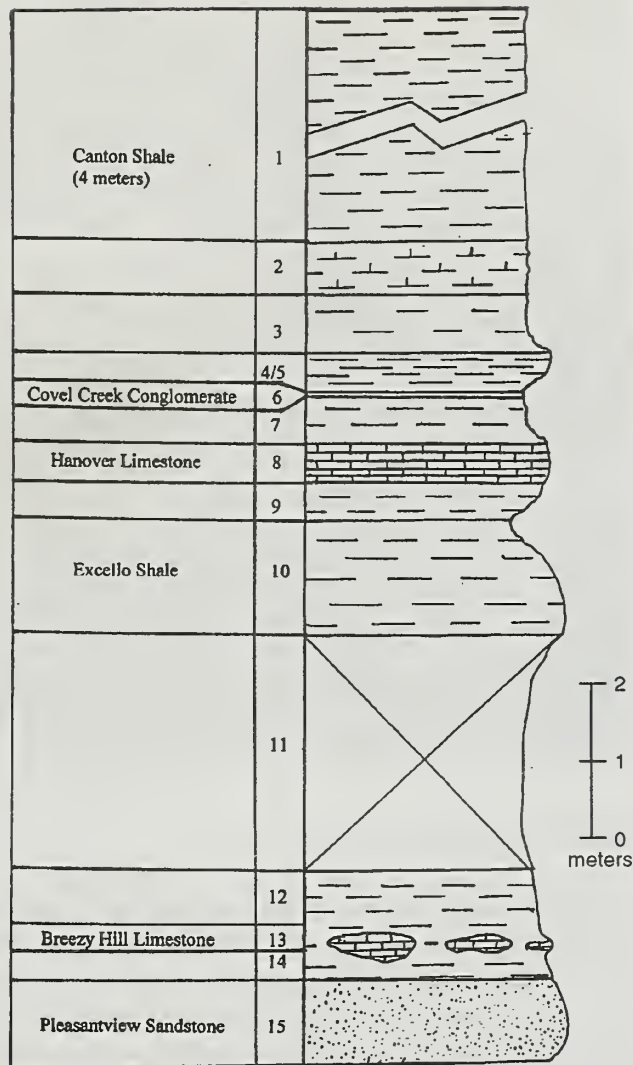


Figure 4-8. Stratigraphic column of the bluff at Mile 2.6 (Stop 2).

Mile 3.0 (Kilometer 4.8)

In a small exposure on the left bank, the Colchester Coal, Francis Creek Shale, and Mecca Quarry Shale can be seen. Participants are traveling down-section, and Galena-Platteville Dolomite dipping at 20° to the southwest is exposed in the riverbed on the right bank a short distance downstream. The exposure is near a wooden truss trail bridge that spans a small gully. This locality is at nearly the same stratigraphic level as at the start of the trip.

Mile 3.3 (Kilometer 5.3)

High bluffs line the right bank of the river for more than 0.25 mi (0.4 km) at this point, with Vermilionville Sandstone forming the upper half of the cliff and Canton Shale forming most of the lower section (fig. 4-9). The contact between the two units is plainly visible through most of the exposure, and many seeps of water can be seen where the Vermilionville aquifer lies perched above the shale. This contact moves to lower elevations as the river flows up-section to the west.



Figure 4-9. Photograph of the Vermilionville Sandstone and Canton Shale at Mile 3.3.

Mile 3.9 (Kilometer 6.3)

Wildcat Rapids A long, south-trending straight reach of river, followed by an abrupt bend to the right, marks the approach to Wildcat Rapids. Wildcat Rapids is located where a barrier of massive boulders of La Salle Limestone partially blocks the river channel (fig. 4-10). At medium to high water levels, the standing waves are sufficient to easily swamp an open canoe, and even rafts will generally take on a moderate amount of water. Depending on water levels, this barrier can create a drop of from 1 to 3 m in the water surface. Below this drop, the river is basically straight and deep, and hydraulic turbulence from the main drop is the primary safety concern.

The right bank is usually considered the best for scouting the rapids, and a well-worn trail leads through the poison ivy-lined banks. Numerous scouting and photographic vantage points can usually be found along this trail. Many rafters opt at this point to carry moisture-sensitive items (e.g., cameras) around the rapids and cache them on the boulders below the drop. Field trip participants who feel apprehensive about the prospect of a close encounter with low temperature, upper flow regime fluid may also avail themselves of the opportunity to walk around the rapids.

Mile 4.1 (Kilometer 6.6)

Stop 3: Former Site of Bailey Falls Up until a few decades ago, Bailey Creek tumbled over this ledge of Hall Limestone in a very scenic waterfall. The tale of Bailey Falls is recounted in the accompanying story by Bill Shields. The bedrock in this area belongs to the Modesto and Bond Formations and consists mostly of limestone; coal and shale occupy greatly diminished portions of the section. This region is well-known among conodont workers for its well-documented conodont



Figure 4-10. Photograph of rafters negotiating Wildcat Rapids.

assemblages (Collinson et al., 1972) and among fossil collectors for the Pennsylvanian marine fossils (especially shark teeth) that have been found in the nearby quarries. The quarry to the south and west is an impressive sight, and it is interesting to look out over the massive excavation and think about the links between this quarry and the Chicago Metropolitan area. As one of the high-quality limestone sources closest to Chicago, a great deal of the La Salle Limestone and other nearby units has been quarried, mixed with clay, fired, and shipped off to the city in the form of portland cement. As the buildings and infrastructure of northeastern Illinois went up, much of this area was going down.

Mile 4.3 (Kilometer 6.9)

Mouth of Bailey Creek.

Mile 4.8 (Kilometer 7.7)

Lone Star Quarry Road crosses the river on an old steel bridge.

Mile 5.9 (Kilometer 9.5)

Lone Star Industries Cement Plant and Dam As the impressive sight of the huge cement plant looms on the left bank, watch for the sign hanging from a cable that warns of the approaching

dam. A steel and concrete retaining wall lines the left bank near the plant, and the group will land on the right bank above the dam. At the southeast end of the dam a spur of concrete projects out and acts as a chute. At certain water levels it is possible to run this chute, but in most instances it is safer to line the unmanned rafts through the opening. The remainder of the dam forms a shear drop with a backroller and is extremely dangerous. If canoeists attempt to run the concrete spur but hit it a little too far to the left, they could become trapped in the backroller. ***Fatalities have occurred at this dam, and it should be treated with great respect.***

Mile 6.1 (Kilometer 9.8)

Approaching the bridge, note the cement “lava flows” and the retaining wall made of cement “pillow lavas.” Below the bridge, there is usually a bit of fast water, the last whitewater of the trip.

Mile 6.7 (Kilometer 10.8)

Two coals are visible on the right bank, just before the power lines. There is little or no exposed rock above or below the coals.

Mile 7.1 (Kilometer 11.4)

Stop 4: Mouth of Deer Creek, Matthiesson State Park The mouth of Deer Creek is one of the most visited and photographed geologic sites in northern Illinois, and a picture of these dipping strata adorns the cover of ISGS Circular 502, *The Galena and Platteville Groups of Northern Illinois* (Willman and Kolata, 1978). The outcrops in the streambank and streambed dip to the southwest at 28 to 30°, providing some of the more dramatic structures that can be found in the largely horizontal strata of the Prairie State. Two creeks enter the Vermilion here, a small steep one coming in from the southeast, and a larger one flowing in through a gorge to the northeast. The larger gorge is the scenic centerpiece of Matthiesson State Park and is well worth the hike necessary to investigate it. East from the Vermilion River, Galena-Platteville strata gain elevation rapidly and soon disappear under a cover of Pennsylvanian strata and Quaternary deposits (fig. 4-11). In the valley of Deer Creek, spectacular cliffs of St. Peter Sandstone frame the canyon and lead to a spectacular waterfall and deep plunge basin. Although an inspection of the map and basic geomorphic intuition would suggest that the easiest route up the canyon would be to follow the creek up from its junction with the Vermilion, this route contains some obstacles that make an upland hike the preferred course. Much of the land in the lower part of the creek valley is subject to a great deal of groundwater discharge, producing deep, low viscosity mud even during periods of drought.

The canyon of Deer Creek appears to have formed as a knickpoint migrated up the valley after base level lowering that occurred during the Pleistocene. However, groundwater sapping may also be playing a role in the formation of this canyon and similar ones in Starved Rock State Park. Similar box canyons in porous sandstones in Florida (Schumm et al., 1995) and Egypt (Luo et al., 1997) have been attributed to the sapping process. Much of the undercutting that is present below Cascade Falls may be the result of the continued seepage of groundwater through the sandstone. Many of the upland areas above the canyon are underlain by the Colchester Coal, which gives this water a rather high sulfur content and a relatively low pH. The cement in the

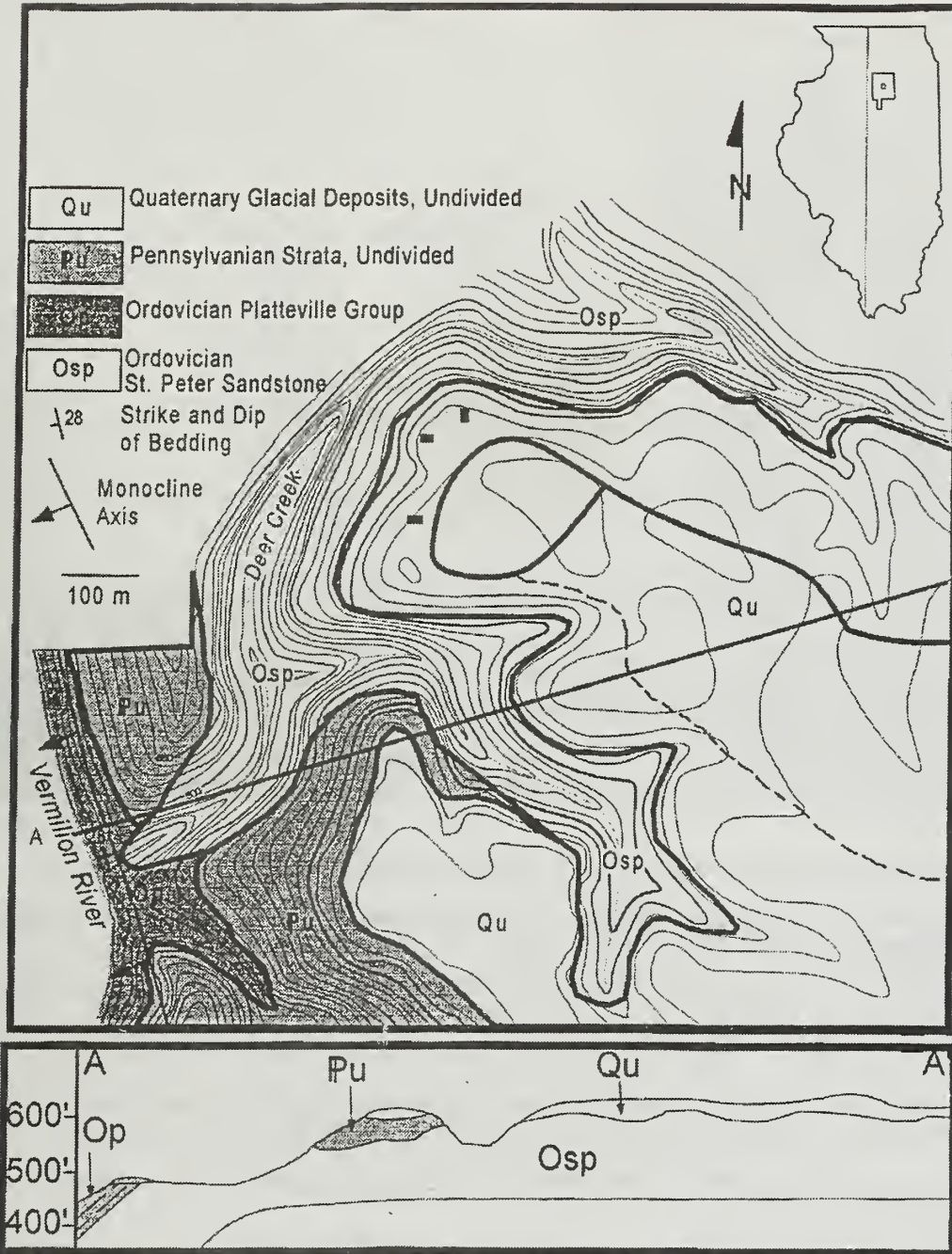


Figure 4-11. Geologic map and cross section of part of Matthiesson State Park (from Nelson and Malone, 1997).

St. Peter Sandstone is weak and largely calcareous, so that this seepage has weakened the lower strata and allowed for the large degree of undercutting. This action, coupled with stream abrasion, has produced some interesting caves near the base of the falls.

Mile 7.9 (Kilometer 12.7)

End of trip. Take out on the right bank and climb out of the gorge. As you trudge up the long hill to the road, you might muse upon the fact that when you started the trip, the river was at an elevation of about 505 ft (154 m) above sea level. At the bridge, the river elevation is approximately 445 ft (136 m) for a total drop of 60 ft (18 m) in almost 8 mi, or 7.5 ft/mi (1.8 m/km). The road shoulder where the vans are parked is around 500 ft again, and a long hike is needed to travel back up the same 60 ft the group descended so easily in the rafts!

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THE TALE OF BAILEY FALLS

—*Bill Shields, Illinois State University and Illinois Department of Transportation, Ottawa, Illinois*

Bailey Falls served as a local picnic area, car wash, and weekend retreat during the early and middle 1900s (fig. 4-12). Families and friends gathered around this communal watering hole to wile away the hot summer days, enjoying the grand stream-fed waterfall and strolling along the



Figure 4-12. Bailey Falls.

scenic wooded river walks. Local seniors recall seeing dozens of families picnicking around the shelters or driving their Model T Fords atop the falls for a free wash. By all accounts, it was an alluring setting that is remembered fondly by residents of the surrounding communities.

According to an article in the local paper authored by John Barron, Bailey's Falls was named for Gus Bailey's parents, who were thought to be the first settlers in the area, having arrived in 1825. Gus, the son of this pioneer family, spent his boyhood near Bailey Falls where his only playmates were Native American children. His family lived on the land until he was 19 years old. It was at this time the Bailey's sold the land to Major G.M. Nelson.

Details pertaining to Major Nelson and his use of the land are unknown, but the story picks up again in 1917. In an essay written by Thomas Trump, a local gentleman, the Bailey Falls property was owned in 1917 by the Bent brothers, who were instrumental in the development of the local community. Centering around a thriving coal mining business, the brothers developed residential subdivisions, built stores, and provided the necessities of life that the mining community needed. Among their assets was the Bailey Falls area, which was used as a dairy farm.

As the Bent brothers harvested the bounty of the Pennsylvanian age Herrin (No. 6), Springfield (No. 5), and Colchester (No. 2) Coals, the Marquette Cement Company was doing the same to the La Salle Limestone, which was adjacent to and above the Bent's operation. It is not clear who threw the first stone, so to speak, but accusations flew, and lawsuits were filed over whose

blasting was endangering whose tunnels. In the end, Marquette Cement acquired Bailey Falls, and the Bent Company was out of business.

In 1932, Bailey Falls was donated to Vermilion Township, and the area was opened to the community for picnics, camping, and swimming. In 1967, Marquette Cement Company bought the land from the township and maintained the recreational area.

In 1974, the cement company was given the mineral rights to the property and began a strip mining operation. In order to quarry the limestone at depths below that of Bailey Creek, the falls had to be destroyed. Knowing this would not be popular among the locals, Marquette Cement Company vowed to restore the falls to their original splendor when the quarry was closed.

Around 1984, during an exceptionally wet spring, Bailey Creek eroded down through the quarry's limestone floor and some fifteen feet of underlying shale, changing the creek's direction of flow and the location of its discharge into the Vermilion River. The new mouth of Bailey Creek can be seen several hundred feet downstream from its original location.

The quarry through which Bailey Falls runs has long been abandoned. The property presently belongs to Lone Star Industries. The falls were never restored, and nature is reclaiming the area in a most spectacular way. Beavers have constructed several dams, flooding acres of quarry floor, which accommodates migratory waterfowl. Herds of white-tailed deer graze the acres of higher flatlands, and red-tailed hawks circle above. Mother Nature has even created a new waterfall on Bailey Creek about a mile upstream from the old one. Although the land is not open to the public, locals still remark about the beauty of Bailey Falls and the surrounding area.

GEOLOGIC HISTORY OF THE AREA: INTERPRETING THE ENVIRONMENTS OF DEPOSITION

—*Mike Phillips, Illinois Valley Community College*

One enjoyable aspect of geology is examining rocks and trying to imagine the environment in which they were deposited. A rationale for wanting to understand the environment of deposition (EOD) is illustrated by the often heard phrase, "the present is the key to the past." To interpret the EOD, the deposit and its fossils are compared with modern environments to locate a "best fit." This process sounds simple, but the geologist must account for the many changes in life, global climate, atmospheric composition, and even the tidal cycle. Therefore, the area of EOD interpretation needs to be entered carefully and with an open mind.

These formations are encountered along the Vermilion River:

- Ordovician Galena-Platteville Formation
- Pennsylvanian Carbondale Formation (cyclothems)
- Ordovician St. Peter Sandstone

Galena-Platteville Formation

The first of these formations encountered along the field trip route is the Galena-Platteville Formation. The interpretation begins by describing the lithology and any fossils found:

The rock is limestone with flat to wavy bedding and abundant bioturbation. There are many marine fossils including brachiopods and *Receptaculites*, a colonial organism (currently interpreted as an algae). The beds vary from thin to thick bedded. The limestone unit is up to 116 m (380 ft) thick in the field trip area.

These observations indicate much about the EOD, including its stability.

Limestone is deposited primarily in marine environments, specifically, on the continental shelf, away from sources of clastic sediments (such as sand, silt, and clay). The presence of abundant fossil life indicates relatively shallow water (especially true if *Receptaculites* is indeed an algae). The overall thickness of the limestone indicates an environment that was relatively stable for millions of years.

Carbondale Formation

The Carbondale Formation is very different. It comprises thin beds of widely varying composition. Early researchers recognized that these beds occur in repeating sequences, which provide an excellent, compact illustration of several EODs. Several are noted here:

- The base of the sequence is marked by a “dirty” sandstone with an uneven lower surface that cuts into the underlying strata. The sandstone is thickly to thinly bedded, may be cross-bedded, and is commonly interbedded with thin layers of clay near the top. This layer is interpreted as river sands deposited in channels eroded into the underlying strata. In places, thin layers of clay show rhythmic changes in thickness that can be associated with tidal cycles.
- The fourth and fifth members of the sequence (counting from the bottom) are claystone overlain by coal. The clay is interpreted as the soil on which the coal swamp grew. Modern coal-forming environments are found primarily in tropical to sub-tropical regions. The most difficult aspect of interpreting the ancient climate is the difference in vegetation. Pennsylvanian coal swamps were filled with tree-size relatives of modern club mosses, scouring rushes, ferns, and now-extinct groups; modern coal-forming swamps contain mostly conifers and flowering plants.
- The seventh and ninth members are limestones with abundant marine fossils, and the eighth member is a black, slaty shale, which also contains some marine fossils. As mentioned, the limestones represent a shallow marine environment. The black shale is a deeper marine deposit, and the black color is related to the low-oxygen conditions found below the photic zone where photosynthesis occurs.

Together, these layers (and the intervening ones not described) represent a constantly changing environment (in geologic terms) that indicates frequent changes in sea level. Geologists are faced with the challenge of providing a reasonable explanation for all of those sea level changes. Explanations have ranged from changing lobes of a large delta system to fluctuations in sea-floor spreading rates to glacial advances and retreats.

St. Peter Sandstone

The St. Peter Sandstone shows a third type of environment. The St. Peter is a very clean sand with “frosted” sand grains and contains no fossils in our area. Its layers are thickly to thinly bedded with some cross-bedding.

The lack of fossils makes the task of interpretation somewhat difficult. However, this problem with sandstones is common because they are deposited in higher energy environments. Cross-beds are commonly found in wind-blown sand, but may be found in other environments. The cleanness of the sand indicates that this is probably not a river deposit. The St. Peter is interpreted as a marine sand based on some marine fossils found in other exposures of the formation. The cross-beds could be indications of aerial exposure along a beach, where sea breezes blow exposed sand in to dunes.

These examples merely “scratch the surface” of possibilities in the interpretation of environments of deposition. The most exciting aspect of this method for teaching applications is the progression from observation to hypothesis to testing of conclusions. The comparison of sedimentary rocks (and fossils) to modern environments is the core of historical geology.

